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ABSTRACT

This student guidebook is designed for use with the study booklets in modules 32 through 34 included in the military-developed course on basic electricity and electronics. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instructional and curriculum development in a civilian setting. An introductory section gives an orientation to the guide and a safety notice. The remainder of the guide contains a summary and a progress check test for each lesson included in the modules. Where applicable, the guide contains instruction sheets for job programs and fault analysis (paper troubleshooting) and actual performance troubleshooting tests. (LRA)

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ED190905

CHIEF OF NAVAL EDUCATION AND TRAINING

CNTT E-060

JULY 1980

Military Curricula for Vocational & Technical Education

BASIC ELECTRICITY AND ELECTRONICS.

MODULE 32: INTERMEDIATE OSCILLATORS.
MODULE 33: SPECIAL DEVICES.
MODULE 34: LINEAR INTEGRATED CIRCUITS.

STUDENTS GUIDE.

CE 026 590

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
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Springfield, IL 62777
217/782-0759

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The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
The Ohio State University · 1960 Kenny Road · Columbus, Ohio 43210
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

PREPARED FOR

BASIC ELECTRICITY AND ELECTRONICS

CANTRAC A-100-0010

MODULE 32

INTERMEDIATE OSCILLATORS

MODULE 33

SPECIAL DEVICES

MODULE 34

LINEAR INTEGRATED CIRCUITS

PREPARED BY

NAVAL EDUCATION AND TRAINING
PROGRAM DEVELOPMENT CENTER DETACHMENT

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GREAT LAKES, ILLINOIS 60088

STUDENT'S GUIDE

JULY 1980

FOREWORD

This Student's Guide has been prepared to aid you in your progress through the self-paced Basic Electricity and Electronics Course. Many of the general instructions applicable to learning materials in earlier lessons will apply equally well in this module set. However, there have been some additions in this series which you should know about. The most notable changes are listed below and should be reviewed prior to beginning your study of the learning materials.

Paper Troubleshooting (fault analysis).

Performance Test Troubleshooting Procedures.

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SAFETY NOTICE

I- Introduction

In the performance of his normal duties, the technician is exposed to many potentially dangerous conditions and situations. No training manual or set of rules can make working conditions completely safe. However, it is possible for you as a technician to complete a full career without serious accident or injury if you are aware of the main sources of danger and if you remain constantly alert to these dangers. You must observe the proper precautions and practice the basic rules of safety consciousness until they become second nature to you.

All rating manuals contain some safety information. Of particular worth is the Standard First Aid Training Course, NAVEDTRA 91217-H. In addition, directives concerning safety are published by each major command on specific hazards and procedures falling under the cognizance of that command. The Chief of Naval Operations has issued a listing of specific precautions compiled by the Department of the Navy. This publication cross-references safety directives by subject matter and by the identifying designation.

Some of the major hazards you will encounter as a technician and some of the basic precautions that you must observe are listed in this section. Although many of these hazards and precautions are general and apply to all personnel, some of them are peculiar or especially applicable to personnel concerned with electronic maintenance.

II- General Safety Rules

Most accidents that occur in noncombat operations can be prevented if the full cooperation of personnel is gained and if care is exercised to eliminate unsafe acts and conditions. The following are some general safety rules that apply to personnel in all types of activities:

1. Report any unsafe condition or any equipment or material considered to be unsafe.

2. Warn others who are believed to be endangered by known hazards or by their failure to observe safety precautions.

3. Wear available protective clothing and use equipment that has been approved for safe performance of work or duty.

4. Report any injury or any evidence of impaired health occurring in the course of work or duty.

5. Exercise reasonable caution when any unforeseen hazard occurs.

III- Electrical Safety Precautions

Take time to be safe when working on electrical circuits and equipment. The following precautions, when carefully and thoughtfully observed, make the difference between a safe sailor and a sorry one:

1. Remember that electrical equipment frequently has more than one source of power. Opening main power supply switches will not necessarily "kill" all power to a given piece of equipment. Heaters and synchros, for example, may receive power from a remote source with no local switch or breaker available. Be certain that ALL power sources are de-energized before servicing ANY piece of equipment.

2. Remember that the 120 VAC line power supply voltage is not a low, relatively harmless voltage. It is the voltage that has caused more deaths in the Navy than any other.

3. Do NOT work alone with high-voltage circuits. Have a person (safety observer) who is qualified in administering first aid for electric shock present at all times. The man stationed nearby should also know the location of the circuits and switches controlling the equipment and should be prepared to secure the power switches immediately if anything unforeseen happens.

4. Equipment containing metal parts (brushes, brooms, and so forth) should not be used in an area within 4 feet of any high-voltage circuits or electrical wiring having exposed surfaces.

5. Keep clothing, hands, and feet dry at all times. When it is necessary to work in wet or damp locations, use a dry platform or wooden stool to sit or stand on and place a rubber mat or other nonconductive material on top of the wood. Use insulated tools and insulated flashlights of the molded type when required to work on exposed parts.

6. Do not wear loose or flapping clothing. The use of thin-soled shoes with metal plates or hobnails is also prohibited. Safety shoes with nonconducting soles should be worn if available. Flammable articles, such as celluloid cap visors, should not be worn.

7. Before working on an electrical apparatus, remove all rings, wristwatches, bracelets, ID chains and tags, and similar metal items. Care should be taken that the clothing does not contain exposed zippers, metal buttons, or any type of metal fastener.

8. Use one hand when turning switches on or off.

9. Make certain that the equipment is properly grounded. Ground all test equipment to the equipment under test.

10. When measuring circuits of over 300 volts, do not hold the test probes.

IV- First Aid for Electric Shock

Electric shock is a jarring, shaking sensation, resulting from contact with electrical circuits or from the effects of lightning. The victim usually feels that he has received a sudden blow. If the voltage and resulting current are sufficiently high, the victim may become unconscious. Severe burns may appear on the skin at the place of contact. Muscular spasms may occur which cause the victim to clasp the apparatus or wire. As a result, the victim may go into shock and be unable to release his grip.

The following procedure is recommended for the rescue and care of electric shock victims:

WARNING

> DO NOT ATTEMPT TO ADMINISTER FIRST AID OR COME IN PHYSICAL CONTACT WITH AN ELECTRIC SHOCK VICTIM BEFORE THE POWER IS SHUT OFF, OR, IF THE POWER CANNOT BE SHUT OFF IMMEDIATELY, BEFORE THE VICTIM HAS BEEN REMOVED FROM THE LIVE CONDUCTOR.

1. Shut off the power.

2. If power cannot be deactivitated, per Step 1, revove the victim immediately, observing the following precautions:

   a. Protect yourself with dry insulating material.

   b. Use a dry board, belt, dry clothing or other available nonconductive material to free the victim (by pulling, pushing, or rolling) from the power carrying object. DO NOT TOUCH the victim.

3. Immediately after removal from the power-carrying object, determine whether or not the victim is breathing.

4. If the victim is breathing, keep him lying down in a comfortable position and loosen the clothing about his neck, chest, and abdomen so that he can breathe freely. Protect him from exposure to cold, and watch him carefully. If the victim is not breathing, apply artificial respiration without delay, even though he may appear to be lifeless. Do not stop artificial respiration until medical authority pronounces the victim beyond help.

5. Keep the victim from moving about. In this condition, the heart is very weak, and any sudden muscular effort or activity on the part of the victim may result in heart failure.

6. Do not give stimulants or opiates. Send for a medical officer at once and do not leave the patient until he has adequate medical care.

For complete information on administering artificial respiration and treating burns, refer to the Standard First Aid Training Course.

V- Electrical Fires

In case of an electrical fire, the following steps should be taken:

1. De-energize the circuit.

2. Call the Station fire department if on a shore base; if aboard ship, call the OOD.

3. Control or extinguish the fire, using the correct type of fire extinguisher.

4. Make reports as required by local directives.

For combating electrical fires, use a CO2 (carbon dioxide) fire extinguisher and direct it toward the base of the flame. Carbon tetrachloride should never be used for firefighting since it changes to phosgene (a poisonous gas) upon contact with hot metal, and even in open air this gas creates a hazardous condition. The application of water to electrical fires is dangerous; and foam-type fire extinguishers would not be used since the foam is electrically conductive.

In case of cable fires in which the inner layers of insulation or insulation covered by armor are burning, the only positive method of preventing the fire from running the length of the cable is to cut the cable and separate the two ends.

NOTICE

SPECIAL HANDLING OF MOS DEVICES

The MOS metal oxide semiconductor devices have a fairly high input resistance making them subject to damage from charges of static electricity through improper handling. The thin layer of oxide can be damaged from discharges of static electricity or improper handling in or out of circuit. The damage may be apparent immediately or may show up only after a short operating time. To avoid possible damage, the following procedures should be followed when handling or testing these devices.

1. The use of synthetic clothing such as nylon should be avoided as this will generate static charges. Dry weather (relative humidity less than 30%) also tends to increase static buildup.

2. Keep the leads of the device in contact with a conducting material or shorted, except when testing, inserting or removing from the circuit.

3. A wrist strap with a megohm resistor in series to common ground should be worn by the technician when inserting, removing or testing MOS devices.

4. Do not remove or insert an MOS device with the power to the circuit or test instrument "ON".

5. Do not apply or inject test signals into the circuit when an MOS device is used with the circuit power "OFF".

6. Do not turn the circuit power "ON" with an MOS device removed from the circuit. Charges can build up causing possible damage when the device is replaced in the circuit.

7. Soldering iron tips, metal bench tops, test equipment and tools should be grounded to a common ground along with the chassis of the set being serviced.

8. Soldering guns should not be used in MOS circuits, AC line leakage from the gun tip could cause damage to an MOS device.

9. Do not apply heat for longer than 10 seconds or closer than 1/16 of an inch to any MOS device when soldering. Use of a heat sink is recommended to prevent damage to the advice.

10. Use the lowest wattage soldering iron possible when removing or inserting MOS devices on printed circuit boards.

HOW TO USE THE STUDENT'S GUIDE

These guides are designed for you to use, along with the learning materials contained in the Study Booklets for each module, and additional or enrichment materials where applicable, while you are taking this segment of the Basic Electricity and Electronics course. The guides are yours to keep and may be taken with you when you complete the training.

Take a minute now to read the Foreword, the Safety Notice, and the Orientation sections carefully before you begin to study the subject matter.

These guides contain a summary and a progress check test for each lesson you will study. You may use the summary as a preview of the lesson or, after completing study of the learning materials, as a review before taking the lesson test.

When you have studied the lesson and feel you understand it, and before taking the lesson test, you should take the progress check. Although it is a test, the progress check is not considered a part of the formal testing program because you administer it yourself. Its purpose is to help you determine whether or not you have mastered the lesson objectives.

For certain lessons, these guides also contain the information and instruction sheets you will need for the job programs and the fault analysis (paper troubleshooting) and actual performance troubleshooting tests which must be completed in order to show you have mastered the lesson terminal objectives.

ORIENTATION

STUDENT'S GUIDE

JULY 1980

COURSE MISSION

The mission of this course is to train personnel who are ordered to specified A schools to demonstrate the applied skills and knowledges of basic electricity and electronics that have been designated by each of the schools to be entry-level prerequisites.

The terminal objectives for Modules 32 through 34 of this course are listed below. Unless otherwise stated, 100% accuracy is required.

32.1.56 IDENTIFY the schematic diagrams, component functions, and operational principles of series-fed and shunt-fed Hartley oscillator circuits, including the accomplishment of phase-shift action, by selecting statements from a choice of four.

32.2.57 TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in RC phase-shift oscillator circuits when given a training device, prefaulted circuit board, necessary test equipment, schematic diagram and instructions.

32.3.58 IDENTIFY the schematic diagrams, component functions, and operational principles of various Wien-bridge oscillator circuits, including the accomplishment of phase shift, regenerative and degenerative feedback, frequency variation, and automatic gain control, by selecting statements from a choice of four.

32.4.59 TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in blocking oscillator circuits when given a training device, prefaulted circuit board, necessary test equipment, schematic diagram and instructions.

32.5.60 IDENTIFY the properties and characteristics of crystals, the component functions and modes of operation of Pierce and tickler coil crystal oscillator circuits, and techniques for adjusting the operating frequency of crystals by selecting statements from a choice of four.

33.1.61 IDENTIFY the purpose, function and operational characteristics of electromechanical and electromagnetic delay lines by selecting statements from a choice of four.

33.2.62 IDENTIFY the purpose, function, and operating characteristics of dummy loads by selecting statements from a choice of four.

33.3.63 IDENTIFY schematic symbols, operating characteristics and applications for optoelectronic devices (LED, photodiode, phototransistor, photo cell, solar cell, and optical coupler), the varactor diode, and the triac, by selecting statements from a choice of four.

33.4.64 IDENTIFY the schematic symbols, construction, operating characteristics and methods for handling and testing field-effect transistor devices by selecting statements from a choice of four.

34.1.65 IDENTIFY basic characteristics of linear integrated circuits to include definitions of terms, proper handling procedures, pin numbering systems and functions, by selecting statements from a choice of four.

34.2.66 IDENTIFY basic functional characteristics of operational amplifiers to include using gain formulas to calculate the gain of inverting and non-inverting circuit configurations and listing correct troubleshooting methods, by selecting statements from a choice of four.

WHAT A SELF-PACED COURSE IS

If you have not been exposed to self-paced instruction, the following information is vital to your understanding the significant differences between conventional and self-paced instruction. For those of you who have experienced self-paced learning, the information following will identify how this particular self-paced course is different from others you may have been exposed to in the past. As you can see by looking around you, each of you has a private carrel rather than a desk facing the learning center instructor. Instead of giving a class assignment, the learning center instructor will give each of you a module containing instructional materials that will instruct you in what you need to learn and what materials are available for study. For example, in the module you may be told that you need to know what is meant by electricity and how an electric current runs through a solid wire. In addition, you will be informed that this information can be found in the summary, narrative, programmed instruction, or an audio visual presentation. At the end of each lesson topic there is a self-check test to help you determine when you have mastered the relevant concepts.

Once you know what resources are available to you, the decisions about which ones to use will be up to you. The other students in the learning center will not necessarily be doing the same thing at the same time. Each of you may choose the material and the method of presenting the material (medium) that is best suited to your particular needs or learning style. You will also decide when to take the progress checks and the module test. You do not have to take them when anyone else does. Once you have successfully "passed" the module test, you will be directed to the next module. At first, you may feel a little uneasy about having to make all these decisions instead of having someone else make them for you; but after a few days, it should become easy. The whole point of this instructional system is to allow you to become involved in the kind of decisions that are usually made by someone else, when, in reality, you are the one person in the best position to make them.

Read all instructions carefully. Many unnecessary mistakes are made and much confusion arises, when people do not read instructions or when they read them carelessly. Don't let yourself fall into that trap.

Learn well. In a group-paced course, it is possible to "slide by" without learning all the points in a lesson, because when the class moves on to the next lesson, everyone has to move. In this course, progress from one module to the next depends on your being able to meet the objectives of each module regardless of what anyone else is doing. Therefore, it is to your advantage to learn the information well before you take any test.

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Use what is available. In this course, there are at least two or more instructional media you can study. If you have studied one type of material and you still do not understand, try studying one of the other media. For instance, if you have read the narrative and do not understand what it is all about, try the programmed sequence or the audio visual presentations. If you have tried alternative materials and still do not understand, ask for help.

Compete against yourself. You are not competing against any other student. It does not matter how well or how fast others achieve. Set your goals. This course is similar to mountain climbing: it is you against the mountain. When you get to the top, you will know that you met the challenge and won.

WHAT'S AVAILABLE AND HOW TO USE IT

I- The Learning Center

Your study area has been designed to provide as much privacy and convenience as possible. All the materials you will need are located at or near your assigned carrel. You will be able to read and study, view audio-visual programs, take tests, and perform job programs and performance tests entirely within the 30 Series learning center.

II- Written Materials

The Study Booklet, one for each module, contains the three major forms of presentation of each lesson. You should begin each lesson by reading the Overview and List of Study Resources. Then select and use one, all, or a combination of the following forms in order to master the knowledge portion of the lesson:

1. Summary. The summary is a condensed version of the lesson, the same one found in the Student Guides. You can quickly read the summary to get an overall picture of what the lesson is all about. If you already have a knowledge of electronics, you may be able to go directly from the summary to the lesson progress check.

2. Programmed Instruction (P.I.) The P.I. presents the lesson in the greatest detail. The information is broken down into small steps, called frames. The student is required to make many responses and thus learns by doing.

3. Narrative. The narrative presents the lesson very much like textbooks you have studied in high school or college. The narrative is more detailed than the summary. It presents the lesson completely.

You are encouraged to try out all three of these forms of presentation and become familiar with them. In that way you will be able to choose the form of each lesson from which you can learn the material most efficiently.

III- Additional and Enrichment Materials

For most lessons, additional forms of presentation (such as sound-slide or video tape programs) and/or other written references are available to supplement the Study Booklet materials. A list of these can be found on the List of Study Resources page following the Overview for each lesson in the Study Booklet.

IV- The Progress Check

When you finish each lesson, take the lesson progress check, located in this guide. Check your answers against those provided. If you miss a question, references are provided to help you restudy the materials. You may take the progress check at any time you feel you are ready. In fact, you may feel free to look over the progress check even before you begin to study the lesson.

V- Job Programs

Many lessons include a job program. Each job program is a laboratory experiment related to the lesson; it is completed before taking the lesson test. The job program reinforces the written lesson and lets you see what you have learned in actual circuits and equipment. It also teaches skills and testing procedures you will need for those lessons which have an actual performance troubleshooting test.

VI- Information Sheets

Many lessons have special test equipment and/or troubleshooting associated with them. To help you understand these areas, information sheets have been included in the guide which provide special instructions about this material.

THE FORMAL TESTING PROGRAM

There are three types of formal tests for the modules in the 30 Series. These are:

(1) knowledge (lesson) tests,

(2) fault analysis (paper troubleshooting) tests, and

(3) performance troubleshooting tests.

All tests are assigned by the computer. Knowledge and fault analysis tests are computer graded. Performance tests are graded by the lab instructor.

Assigned knowledge (lesson) and fault analysis tests will be issued to you by the Learning Center Instructor. Knowledge tests measure achievement of objectives related to material presented in the summary, narrative and P.I.. Knowledge tests should be taken only after mastery of the progress check and completion of the job program, if applicable.

Fault analysis tests measure the ability to think through actual problems related to the circuit or equipment studied in the lesson. They also provide mental practice for the performance test.

Performance tests are actual troubleshooting encounters on prefaulted circuit boards issued by the lab instructor. You should not attempt a performance test until you have successfully completed both a fault analysis test and a practice performance test. Practice performance tests are assigned by the computer before the actual performance test is assigned, but they are not part of the formal testing program. Both practice and actual performance tests are graded by the lab instructor, who feeds the results into the computer.

FAULT ANALYSIS
(Paper Troubleshooting)

Many of the lessons in the 30 series have fault analysis exercises. These paper troubleshooting problems have been designed to help you think about possible solutions to given troubleshooting symptoms. The problems in these exercises are for actual circuits which you will be troubleshooting on the performance test. You should study the symptoms, and then look at the multiple choice answers. Based on your knowledge of the circuit, which you obtained from the Study Booklet and the job program, you should be able to select one of the choices which will produce the given set of symptoms.

MODULE

THIRTY TWO

INTERMEDIATE OSCILLATORS

STUDENT'S GUIDE

JULY 1980

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SUMMARY
LESSON 1

Hartley Oscillators

This lesson explains the operation of the Hartley oscillator, a type of oscillator commonly used in electronic equipments. One application for this oscillator is providing frequency injection for the mixer stage of a superheterodyne radio receiver. When the oscillator is used in this way it is called a local oscillator (LO). The Hartley circuit is also used to provide a variable frequency in radio transmitters and signal generators.

There are two types of basic Hartley oscillators...series and shunt. Both of these oscillators are discussed in subsequent paragraphs and comparable AC circuit schematics are provided. The major advantage of a Hartley type oscillator is that it provides good frequency stability over a wide range of frequencies and produces a constant amplitude sine wave output.

Recall that one of the requirements of any oscillator is the necessity for an in-phase (regenerative) feedback voltage. In order to assure that the regenerative feedback is in phase with the input of the amplifying device, it is necessary to effect a 360 degree phase shift within the oscillator circuit. This is discussed in detail in subsequent paragraphs relating specifically to the Hartley oscillator.

Remember that the function of an oscillator is to produce a constant amplitude stable output signal. Recall also that unless the feedback is regenerative, oscillations cannot be sustained. Since the purpose of feedback is to compensate for internal power loss, it is obvious that when the feedback is exactly in phase, less feedback is necessary to overcome circuit losses. A difference of a few degrees in the phase of the feedback either way still enables the circuit to oscillate. The amplitude of the necessary feedback required to sustain oscillation, of course, is much less when the feedback is exactly in phase. The schematic diagram shown in Figure 1 is the AC equivalent of a Hartley type oscillator.

$$f_O = \frac{1}{2\pi\sqrt{L_t C_t}}$$

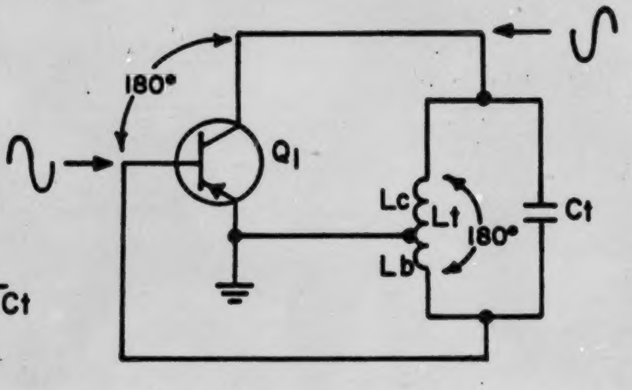
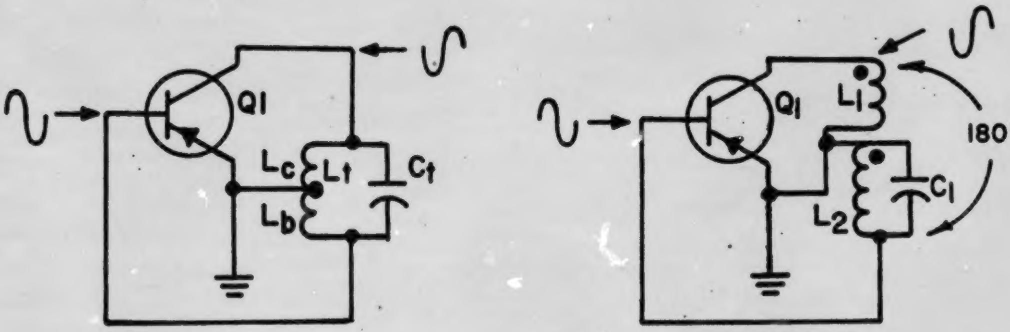


Figure 1

AC EQUIVALENT-HARTLEY OSCILLATOR

Phase shift in the Hartley oscillator is accomplished in a similar way to that of the Colpitts oscillator. If you do not recall how the Colpitts functions, please refer to Module 22, Lesson 4. The main difference between the Hartley and the Colpitts is that the Hartley uses a tapped inductor to provide the 180° phase shift, whereas the Colpitts uses a capacitive voltage divider. In the Hartley type oscillator the tank circuit is excited by the voltage from the collector of the transistor. Look at the schematic and notice that the AC voltage at the bottom of the coil is 180° out-of-phase with the AC collector voltage of the transistor. Waveforms are shown on the schematic in order to help you understand the operation of the oscillator more readily. In this instance, the inductance of the oscillator, specifically L_t, may be considered as an inductive voltage divider. Notice that the inductance in this example is center tapped. In actual practice the tap may be somewhat off center. The actual location of the tap depends on the amount of feedback which is required. Even though the tap may be somewhat off-center, sufficient feedback can still be provided to maintain oscillation in the circuit.

Two simplified AC equivalent schematics are shown in Figure 2. These schematics are for the Hartley and the Armstrong oscillator.



HARTLEY ARMSTRONG

Figure 2

AC OSCILLATOR EQUIVALENTS

In the case of the Armstrong oscillator, feedback is accomplished by transformer action. Notice that the output signal from the collector of Q1 is transformer coupled from L1 to L2 and back to the base of the transistor. This in itself results in a 180° phase shift. The additional phase shift is accomplished by the action of the transistor. Phasing dots have been shown on the schematic to emphasize the phase shift that occurs in the transformer. If the connections of L1 and L2 are reversed, the circuit will stop oscillating. Study the Hartley schematic shown in the Figure and notice that the primary of the transformer is designated as L_c and the secondary section of the transformer is designated as L_b. Although these coils have a common point, mutual coupling still exists between them. Current which flows through L_c induces a voltage across L_b and produces transformer coupling action comparable to the transformer coupling action of the Armstrong circuit. This type of coupling action is often referred to as an "autotransformer action".

Remember that the two major classifications of Hartley oscillators are series and shunt-fed oscillators. Recall also that one of the characteristics of all oscillators is that the amplifier section of the oscillator must be forward biased in order to provide amplification. The schematic shown in Figure 3 is that of a series-fed Hartley oscillator circuit.

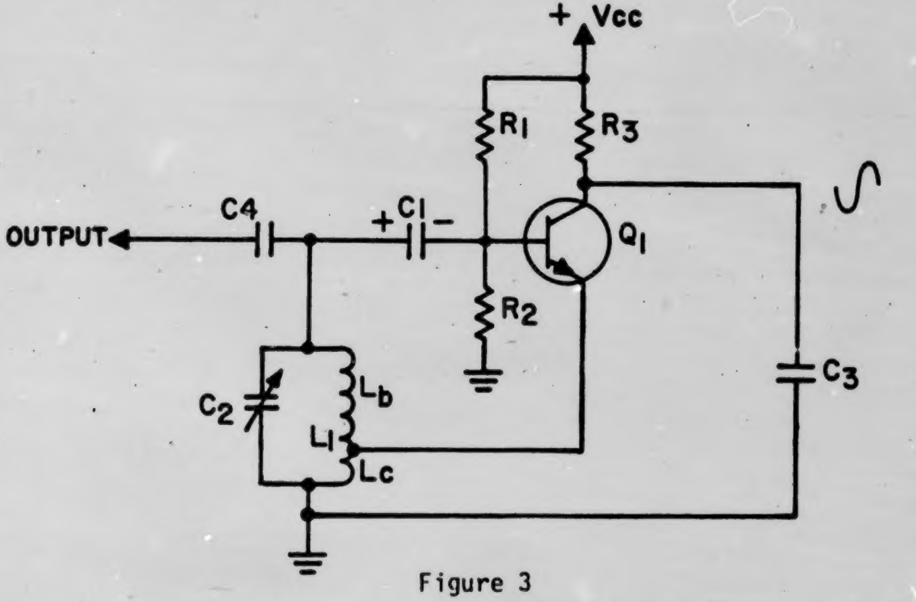


Figure 3

SERIES-FED HARTLEY OSCILLATOR

Examine the schematic and notice that resistors R1 and R2 provide the forward bias for Q1. Current flowing from ground to VCC places the forward bias of Q1 at approximately 0.6 volt positive. Remember that a forward bias is necessary in order for the transistor to conduct and oscillation to begin. Transistor current then flows from ground through the tank coil L_c, Q1, R3 and then back to VCC. This creates a magnetic field around coil L_c which induces a voltage into coil L_b. The polarity of the voltage across L_b causes the forward bias of the transistor to increase, as does the conduction of the transistor. Transistor conduction then follows the voltage across the tank, At the same time, the induced voltage in L_b and L_c start oscillations in the tank circuit. The alternate charging and discharging of C2 causes an exchange of energy from the capacitor's electric field to the inductor's magnetic field. This interaction between the tank capacitor and inductor is sometimes called the "flywheel effect".

The tank circuit has now been shocked into oscillation by the inductive action of L_c and L_b. Remember that once the tank begins to oscillate it will continue to oscillate as long as sufficient regenerative feedback is provided to overcome tank and circuit losses. In this case the tank signal is inverted by Q1 and coupled to the bottom of L_c where the tank circuit inverts the signal another 180°. This provides the positive regenerative feedback necessary to keep the tank circuit oscillating. Remember that the tank continues to oscillate as long as sufficient regenerative feedback is provided to compensate for tank and circuit power losses. You can see from this explanation that an oscillator is basically a tank circuit, an amplifier and a regenerative feedback path.

Refer again to the Hartley schematic shown in Figure 3. When the oscillator commences to oscillate, the base-emitter voltage of Q1 drops to less than 0.6 volt. In some cases, this voltage may even be negative. The reason for this change in voltage is the charge on capacitor C1. In other words, the capacitor develops a voltage across it which opposes the transistor forward bias established by R1 and R2. As you know, this reduces the forward bias of Q1. Refer again to to the schematic shown in Figure 3 and notice that the current passes through coil L_c. Because the DC current flow through coil segment L_c increases the voltage drop across the coil, in some respects the coil acts like a series resistor. Remember that increasing the resistance of a tank coil reduces the Q of the coil and the tank circuit. There is one undesirable effect associated with this and that is that the tank bandwidth increases causing the oscillator to operate at a frequency other than that which was originally intended or desired.

Frequency stability of an oscillator circuit depends on the Q of the oscillator tank. With a high Q, good stability is provided, whereas a low Q tank produces less stability for the oscillator circuit. A method commonly used to improve the frequency stability of an oscillator circuit is to remove the DC current from the tank circuit. This is accomplished by moving the ground from the bottom of the tank to the emitter of Q1.

The modified circuit is shown in Figure 4.

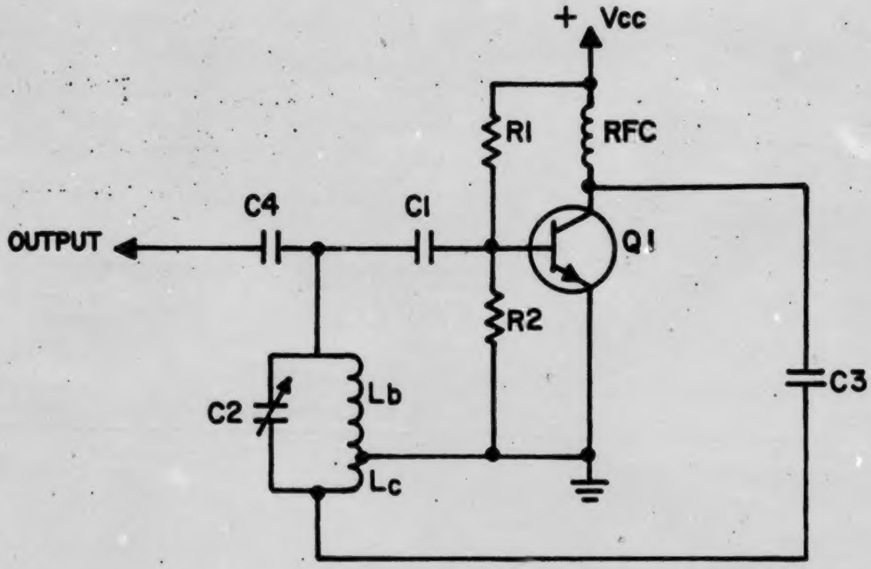


Figure 4

SHUNT-FED HARTLEY OSCILLATOR

This is also the schematic of a shunt fed Hartley oscillator. This type of oscillator has better frequency stability. To further improve the performance of the oscillator, an RFC is used instead of a resistor for the collector load. Because this device has little DC resistance and provides a large AC reactance it keeps the oscillating signal from entering the power supply source and increases the DC collector working voltage. You undoubtedly remember that AC entering the power supply source could cause interference with other circuits using the same power supply as a voltage source. Using the RFC as a collector load is not unique to the shunt-type Hartley oscillator. The RFC could also be used with a series-fed oscillator circuit.

With series and shunt-fed Hartley oscillators, the transistors that are used may be either PNP, or NPN. These circuits may also be represented schematically in a different way.

Two additional examples of Hartley type oscillator schematics are shown in Figure 5.

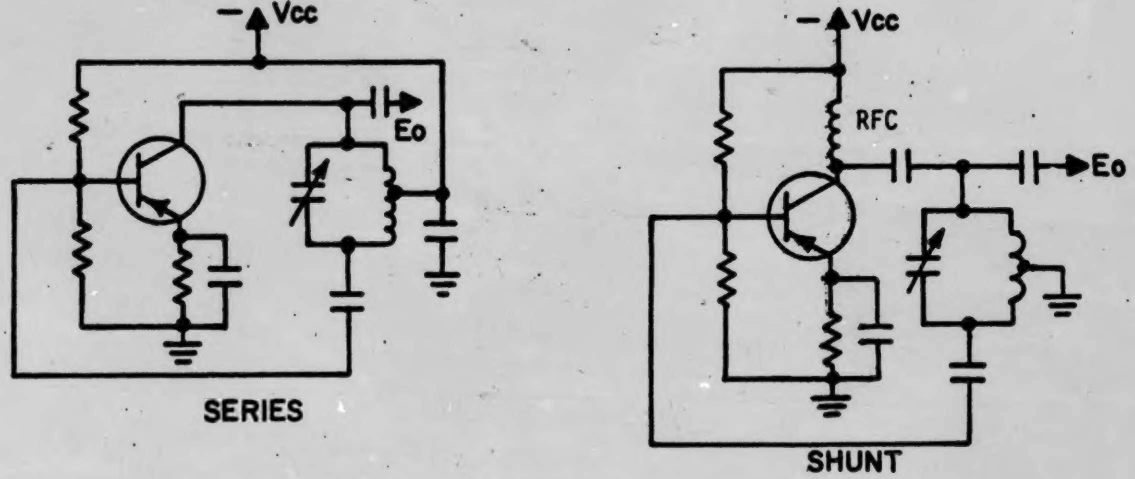


Figure 5

HARTLEY OSCILLATOR SCHEMATICS

As an exercise, trace the DC current paths from ground through the transistor to VCC in order to verify the circuit names. One way of identifying the Hartley type oscillator circuit from other oscillator circuits is to determine whether the tank coil has been tapped. After you determine that the tank coil is tapped, you can easily determine whether the oscillator is series or shunt by tracing the current flow through the transistor. When the tank circuit is in parallel, or in shunt with the transistor, the circuit is a shunt-fed Hartley oscillator. When the transistor current passes through the tank coil, the circuit is a series-fed Hartley oscillator.

It is often necessary to determine the oscillating frequency of an oscillator. You may have used an oscilloscope to make this determination. Because the oscilloscope does not provide the accuracy required, a frequency counter is now the standard piece of test equipment used for determining frequency. The digital frequency counter is more accurate because it minimizes the loading of the oscillator circuit and provides a direct digital read-out of the oscillator frequency. The digital frequency counter is crystal controlled and is accurate to 1 part in 10^8 or 1 hertz in 100 MHz. One such frequency counter which you will have an opportunity to use in the job program is the AN/USM-207.

AT THIS POINT YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 1

Hartley Oscillators

TERMINAL OBJECTIVE(S):

32.1.56 When the student completes this lesson (s)he will be able to IDENTIFY the schematic diagrams, component functions, and operational principles of series-fed and shunt-fed Hartley oscillator circuits, including the accomplishment of phase-shift action, by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVE(S):

When the student completes this lesson, (s)he will be able to

32.1.56.1 IDENTIFY the functions of an LC oscillator and its three sections by selecting the correct statement from a choice of four. 100% accuracy is required.

32.1.56.2 IDENTIFY the operating characteristics of Class A and Class C oscillator circuits by selecting the correct statement from a choice of four. 100% accuracy is required.

32.1.56.3 IDENTIFY the advantages of a Hartley oscillator by selecting the correct description of its characteristics from a choice of four. 100% accuracy is required.

32.1.56.4 IDENTIFY the factors necessary to accomplish phase-shift action in a Hartley oscillator circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

32.1.56.5 IDENTIFY the function of components and circuit operation of series-fed and shunt-fed Hartley oscillator circuits, given a schematic diagram, by selecting the correct statement from a choice of four. 100% accuracy is required.

32.1.56.6 IDENTIFY the schematic diagrams of series-fed and shunt-fed Hartley oscillators by selecting the correct name(s) from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON 1

Hartley Oscillators

1. One function of an oscillator is to

   a. change DC to AC.
   b. change AC to DC.
   c. increase AC output.
   d. decrease DC output.

2. Oscillator feedback must be ______________ in order for the oscillator to continue oscillating.

   a. out of phase
   b. degenerative
   c. regenerative
   d. neutralized

3. A Hartley-type oscillator provides

   a. little input regulation and constant output.
   b. good frequency stability and a constant amplitude sine-wave output.
   c. little frequency stability with a constant sine-wave output.
   d. average frequency stability with reduced output amplitude.

4. A Hartley oscillator tank circuit provides a ______________ for the feedback voltage

   a. damped output
   b. 90° phase shift
   c. 180° phase shift
   d. 360° phase shift

5. 360° of feedback in a Hartley oscillator is accomplished as a result of

   a. tank circuit and amplifier inversion.
   b. the internal action of Q1.
   c. the tank capacitor and inductor.
   d. flywheel effect of the tank.

6. A high tank Q in an oscillator circuit

   a. has no effect on frequency stability.
   b. results in less frequency stability.
   c. results in greater frequency stability.
   d. reduces the output voltage.

7. The Q of a coil in a tank circuit depends on the ratio of

   a. XL/R.
   b. R/XL.
   c. R/XC.
   d. RX/L.

8. The tank circuit in a Hartley oscillator accomplishes both

   a. frequency selection and phase cancellation.
   b. frequency selection and phase inversion.
   c. frequency inversion and phase selection.
   d. frequency inversion and phase cancellation.

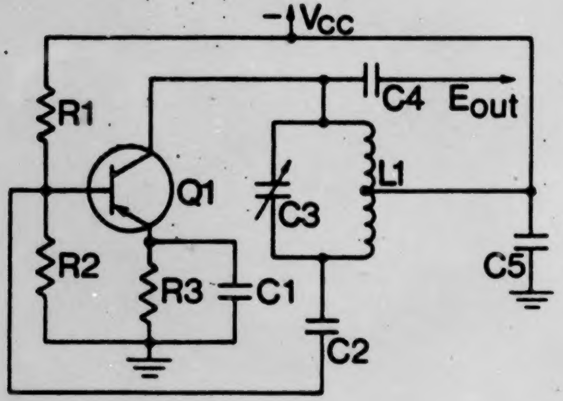
9. One advantage of using a radio frequency choke (RFC) in a shunt type Hartley oscillator is that the choke

   a. has the advantage of little current drain.
   b. is more stable due to an increased resistance.
   c. provides a large AC impedance and little DC resistance.
   d. provides a small AC impedance and large DC resistance.

10. A distinguishing characteristic of Hartley type oscillators is the

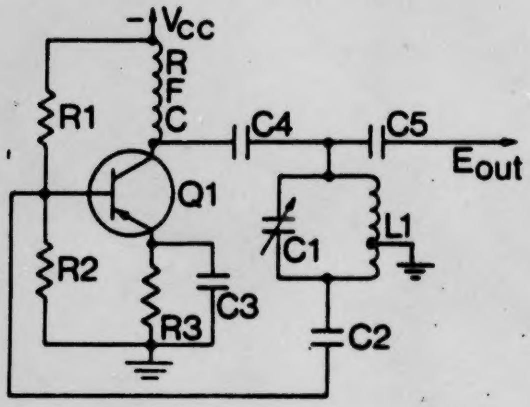
   a. use of NPN transistors.
   b. use of PNP transistors.
   c. variable frequency of the oscillator tank.
   d. tank coil tap.

11. The schematic shown below is that of a


-Vcc
R1
C4
Eout
L1
Q1
C3
C5
R2
R3
C1
C2

a. Colpitts oscillator.
b. Armstrong oscillator.
c. shunt-fed Hartley oscillator.
d. series-fed Hartley oscillator.

12. The schematic shown below is that of a


-Vcc
R1
RFC
C4
C5
Eout
Q1
C1
L1
R2
C3
R3
C2

a. series-fed Hartley oscillator.
b. shunt-fed Hartley oscillator.
c. variable frequency Armstrong oscillator.
d. Colpitts oscillator.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS, (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

JOB PROGRAM
LESSON 1

Hartley Oscillators

INTRODUCTION:

This Job Program is designed to permit you to check the frequency of a Hartley oscillator using the AN/USM-207 frequency counter. Figure 1 will indicate the position of the various controls necessary to complete these measurements. All other front panel controls have not been shown since they are concerned with other measurements which the counter is capable of performing.

TERMINAL OBJECTIVE(S):

32.1.56 When the student completes this lesson (s)he will be able to IDENTIFY the schematic diagrams, component functions, and operational principles of series-fed and shunt-fed Hartley oscillator circuits, including the accomplishment of phase shift action, by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVE(S):

When the student completes this lesson, (s)he will be able to:

32.1.56.7 MEASURE and COMPARE the output frequency of Hartley oscillator circuits, given a training device, circuit boards, test equipment and proper tools, schematic diagrams, and a job program containing reference data for comparison. Recorded data must be within limits stated in the job program.

SAFETY PRECAUTIONS:

Observe all standard safety precautions. Beware of all open and exposed connections; an energized circuit may have dangerous voltages present.

EQUIPMENT AND MATERIALS

1. NIDA 205 Transceiver Trainer
2. AN/USM-207 Frequency Counter
3. BNC-Alligator clip cable (1)

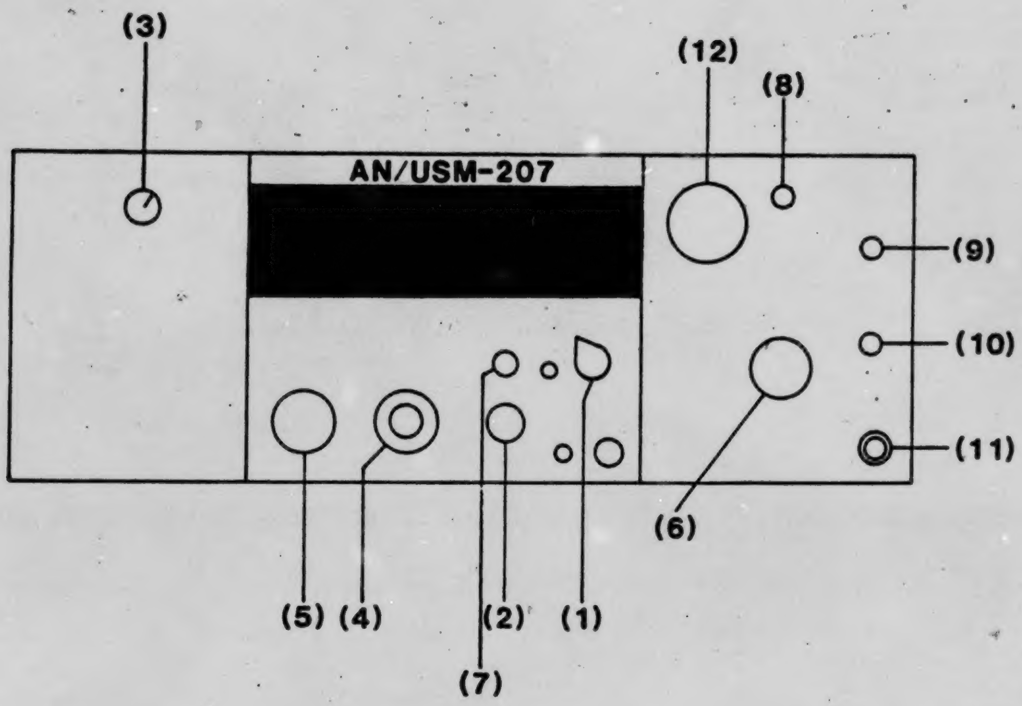


Figure 1

PROCEDURES:

1. Plug in and energize the AN/USM-207 frequency counter. To energize turn the power switch (1) to STBY and observe that both the power on lamp and the oven lamp are lit. Allow at least 5 minutes for warm up then turn the power switch (1) to TRACK. Notice that once the frequency counter is turned on it cannot be accidently turned off. To turn the frequency counter off you must push the small push button at the left of the switch.

2. Set the DISPLAY control (2) one-quarter turn from its maximum CCW position. The DISPLAY control varies the length of time that the count is displayed.

3. Set the SENSITIVITY switch (3) to the PLUG-IN position. The SENSITIVITY switch selects the source of the input signal (test or plug-in) and the amount that the signal is attenuated if the signal is applied to the "FREQ A" jack.

4. Set the TIME BASE switch (4 black knob) to the GATE TIME (SEC-1) to 10^4. The TIME BASE switch selects the unit of measurement (kHz or MHz) and the position of the decimal point.

5. Set FUNCTION switch (5) to the FREQ position. The FUNCTION switch selects the mode of operation (frequency or period).

6. The purpose of RESET switch (7) is to return the display to zero in order to start another count.

7. On the CV-1921/USM-207 FREQUENCY CONVERTER, set the FREQUENCY TUNING-MC switch (6) to 100. Notice that this switch selects frequencies from 100 to 500 MHz in increments of 50 MHz. You must know the approximate frequency applied before using this converter.

8. Set the DIRECT-HETERODYNE switch (8) to HETERODYNE. This position of the switch will mix the input frequency with 100 MHz and display the difference between the two frequencies. By adding the displayed frequency to 100 MHz, you have the frequency applied to the input jack.

9. Set the ATTENUATOR switches (9) and (10) to the 10V MAX position. These switches determine the amount that the signal applied to the converter will be attenuated.

10. (11) is the input connector to the CV-1921/USM-207 frequency converter.

11. (12) is the converter meter and registers the strength of the signal being applied to the counter. If the meter is positioned in the red or low green the signal is not strong enough to drive the counter.

12. Turn the NIDA Transceiver Trainer over and remove the bottom cover. Notice the 3rd tuning capacitor from the front of the transceiver. This is the local oscillator tuning capacitor. Study Figure 2 and notice that this is a Hartley Oscillator.

FREQUENCY CONVERTER

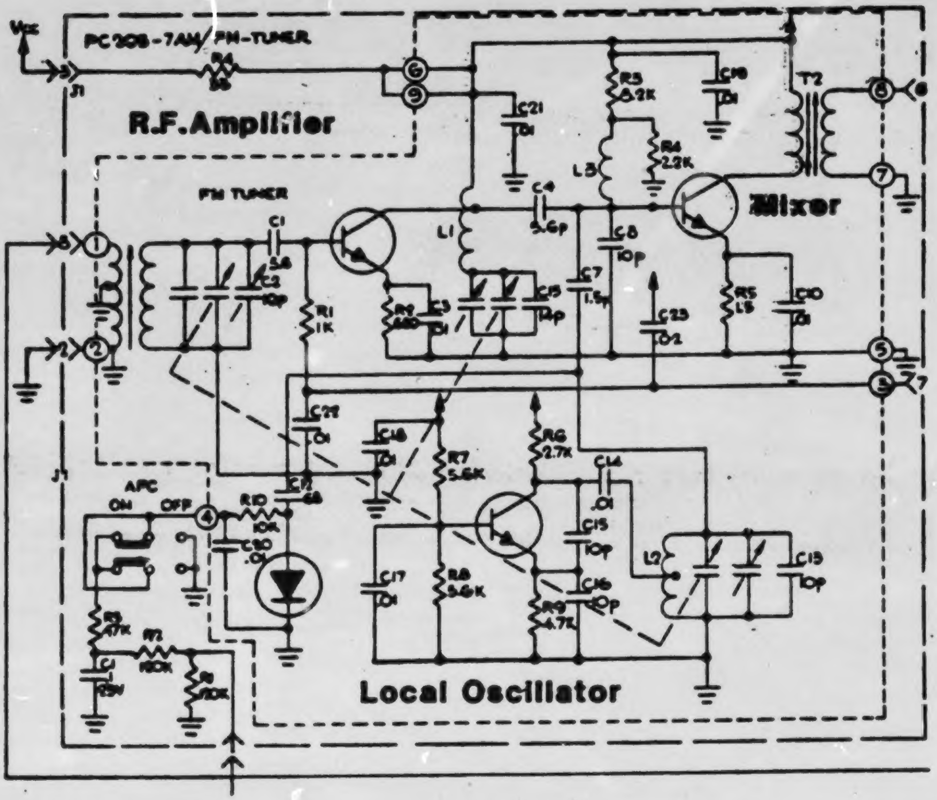

Vcc
PC208-7AM/FM-TUNER
R4
J1
R.F.Amplifier
FM TUNER
C1
5.6
C2
10P
R1
1K
R2
680
C3
.01
L1
C4
5.6P
C15
14P
C7
1.5P
C21
.01
R3
8.2K
R4
2.2K
L3
C8
10P
C18
.01
T2
Mixer
C23
.02
R5
1.5
C10
.01
C22
.01
C16
.01
C12
68
R7
5.6K
R6
2.7K
C14
.01
C15
10P
C16
10P
R8
5.6K
R9
4.7K
C17
.01
L2
C13
10P
AFC
ON
OFF
R10
10K
C20
.01
R3
47K
R2
100K
C1
1
25V
R1
10K
Local Oscillator

Figure 2

13. Connect the RF probe, using the direct position of the probe, to the eye of this capacitor and the BNC connector to the input of the frequency converter. Make certain that the ground lead of the probe is connected to ground.

14. Set the frequency dial on the NIDA 205 Transceiver to 108 MHz.

NOTE: A lower frequency on the dial may not produce sufficient oscillator output to trigger the AN/USM-207 frequency counter.

15. Plug in and energize the NIDA 205 Transceiver. A reading should appear on the frequency counter display. If a reading does not appear set the attenuator switches on the frequency counter to the 0.3V position.

NOTE: When you studied FM IF amplifiers you learned that a common IF was 10.7 MHz. The Local Oscillator frequency in this receiver is tracking above the incoming RF frequency. As an example of this, assume that you are receiving a station transmitting on 104.0 MHz FM. The Local Oscillator is therefore operating at a frequency of 114.7 MHz or 10.7 MHz above the station frequency. Since the frequency converter in the frequency counter is producing 100 MHz and is mixing with the Local Oscillator frequency of 114.7 MHz then the frequency counter should indicate the difference between the two frequencies or 14.7 MHz.

16. From the information given in steps #8, #14 and the above note, answer the following questions.

    a. What is the frequency shown on the frequency counter? ___________ MHz.

    b. What is the frequency of the Local Oscillator? _________________ MHz

    c. What is the frequency of your FM station? _______________________ MHz.

17. Move the TIME BASE switch (4-black knob) CCW step by step and notice the position of the decimal point. The more numbers you have to the right of the decimal point, the more accurate will be your reading.

18. Turn the fine frequency dial on the NIDA 205 Transceiver to 100 MHz. Notice that the frequency counter indication is decreasing toward zero. Refer to step #8 and you will understand that the difference between the frequency applied and the frequency of the counter is zero. Notice, also, that as you do this the counter display becomes unstable and accuracy is lost.

NOTE: Go through your own selection of frequency settings on the dial of the NIDA 205 transceiver and do the calculations in step #16 until you completely understand the operations for frequency measurements using the AN/USM-207.

You have now completed the Job Program on the Hartley oscillator. As you noticed in Figure 2, the Local Oscillator on the NIDA 205 Transceiver is a Hartley oscillator. You have seen how the frequency of the oscillator was changed so that the IF would remain the same. You have also learned how to measure frequency using the AN/USM-207 frequency counter. This same counter is used on many ships and stations throughout the U.S. Navy.

CHECK YOUR RESPONSES TO THIS JOB PROGRAM WITH THE ANSWER SHEET. IF YOUR RESPONSES AGREE WITH THE ANSWER SHEET, YOU MAY TAKE THE LESSON TEST. IF YOUR RESPONSES DO NOT AGREE OR IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THIS JOB PROGRAM, REVIEW THE PROCEDURES OF THIS JOB PROGRAM, ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS, OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR UNTIL YOUR RESPONSES DO AGREE.

SUMMARY
LESSON 2

RC Phase Shift Oscillator

When you previously studied LC oscillators you learned how the LC tank circuit and amplifier accomplish a 360 degree phase shift. You also learned that the purpose of this phase shift was to provide regenerative feedback for the oscillator circuit. Recall that the purpose of regenerative feedback is to compensate for internal power losses within the circuit and that without this feedback, the circuit will stop oscillating.

Other methods besides an LC tank circuit may be used in order to provide phase shifting. One such method for accomplishing the phase shift is to use a series of RC networks. Remember that an RC network is made up of a resistor and capacitor. Also recall that the ICE rule of thumb states that the current through a capacitor leads the voltage across it by 90 degrees. This means that a capacitor can cause a 90 degree phase shift. In actual application, however, this amount of shift cannot be realized. This is due to the fact that a resistance is required in the circuit in order to produce an output voltage. Therefore, when a capacitor is combined with the resistance the maximum possible phase shift of the voltage across the resistor may approach 90 degrees but cannot equal it.

If you do not remember how phase shifting is accomplished by using an RC network, refer to lesson 2 of module 12. Since one phase shift network cannot accomplish a 90 degree phase shift, it is necessary to use three or more networks in order to achieve the necessary 180 degree shift. A minimum of three RC networks is generally used. The schematic diagram shown in Figure 1 depicts a 3-section RC phase shift network.

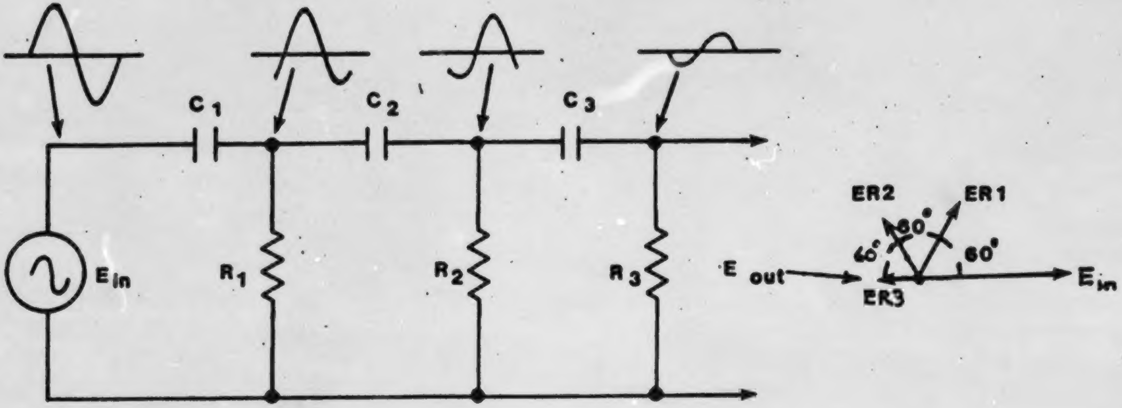


Figure 1

3-SECTION RC PHASE SHIFT NETWORK

For ease in understanding, each of the networks shown in Figure 1 shows a 60 degree phase shift. In actual practice, each of the RC networks will accompish phase shifts that are in the vicinity of 60 degrees. You may encounter a phase shift network of this type, where two of the networks effect a 75 degree phase shift and third network provides the additional 30 degrees of shifting. The most important thing for you to remember in regard to this is that the three networks combined accomplish the 180 degree shift. In addition to the schematic diagram, waveforms are shown immediately above each of the RC networks. These waveforms are used to illustrate the concept that the amplitude and phase of the input voltage is modified by each of the RC networks. The waveforms show that the amplitude decreases with each succeeding RC network. In addition to the waveforms, vectors are shown immediately to the right of the schematic diagram. These vectors also indicate the change of magnitude and phase shift provided by each RC network. Even though a 60 degree phase shift is indicated, remember, in actual practice, the phase shift may be somewhat more or less than the 60 degrees shown. Also recall that the total shift must be 180 degrees. You will sometimes encounter four section networks, and these networks provide approximately 45 degrees of phase shift per network.

The schematic diagram shown in Figure 2 is that of an RC phase shift oscillator circuit.

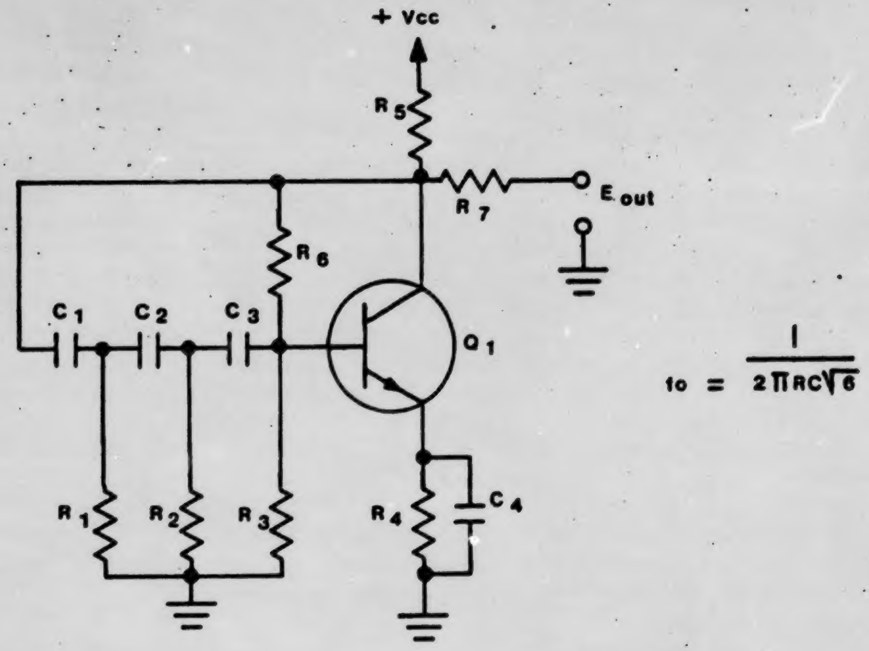

+ Vcc
R5
R7
E out
R6
C1
C2
C3
Q1
R1
R2
R3
R4
C4
fo = 1 / 2πRC√6

Figure 2

RC PHASE SHIFT OSCILLATOR CIRCUIT

The circuit shown accomplishes a 360 degree total phase shift from base, to collector, to base. The RC network accomplishes 180 degrees of the shift, whereas transistor Q1, in addition to amplifying the signal, contributes the other 180 degrees of phase shift. The amount of amplification provided by the transistor depends on the transistor's voltage gain.

The phase shifting network of the schematic shown in Figure 2 consists of resistors R1, R2, R3 and capacitors C1, C2 and C3. Although each RC section is capable of providing approximately 60 degrees of phase shift in actual practice, the phase shift provided by each of the networks may vary. Nevertheless, the three networks together provide a combined shift of 180 degrees. Components other than those which make up the RC network make up a standard common emitter type amplifier. Forward bias for the transistor is provided by the voltage divider from VCC to ground through resistors R3, R5, and R6. This resistance network establishes a voltage at the base of Q1 of about 0.6 volts positive in respect to the ground. In addition, a small amount of negative feedback is introduced by connecting R6 between the collector and base of Q1. This degenerative feedback improves the purity of the sinewave output signal. R5 functions as the collector load resistor for Q1, whereas the R4-C4 combination provides emitter stabilization action for the transistor. Resistor R7 couples a portion of the collector's signal of Q1 to the output terminals and isolates the oscillator from the load. Concerning this type of circuitry, it is possible to use either NPN or PNP transistors. The output of this oscillator circuit must be sufficient to provide a regenerative signal of adequate magnitude to compensate for internal power losses of the oscillator. As you undoubtedly know, if this is not provided, the oscillator will stop oscillating.

The output frequency of RC oscillators may be changed by changing the values of the resistors and capacitors which make up the individual RC networks. Increasing the resistance or capacitance of the components which make up the network results in a decrease in the output frequency. Conversely, a decrease in the resistance or capacitance of the network components results in an increase in the output frequency. This relationship is shown by the formula for the oscillating frequency.

The schematic diagram shown in Figure 3 is that of a variable frequency RC phase shift oscillator.

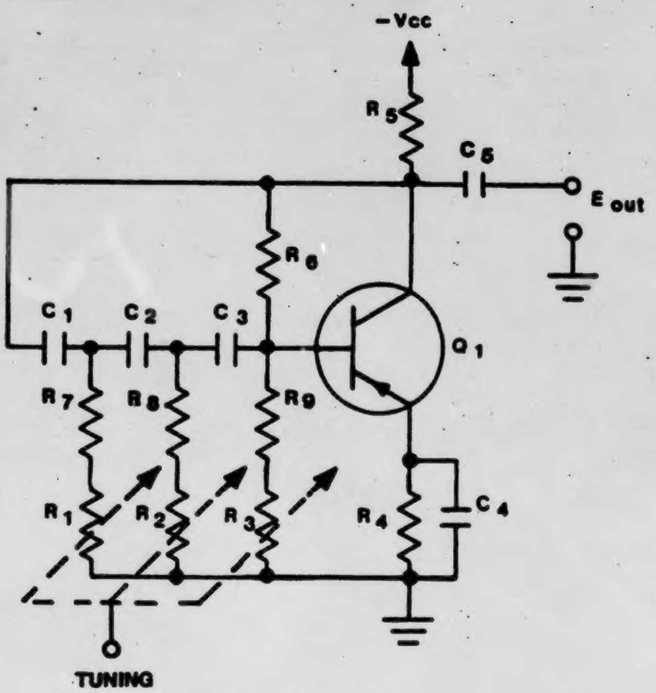


Figure 3

VARIABLE FREQUENCY RC PHASE-SHIFT OSCILLATOR

The addition of the ganged variable resistor allows the output frequency to be varied over a limited range. Notice that the variable resistors are part of the resistance of the phase shift network. Another technique which is sometimes used to vary the oscillator output frequency is to use ganged variable capacitors. Remember, the actual oscillating frequency of the oscillator may be determined by substituting in the formula: $F_0 = \frac{1}{2\pi RC\sqrt{6}}$ In this example the values of each of the RC networks is identical.

The oscillator circuit shown in Figure 3 provides a pure, nondistorted sinusoidal output waveform. Because there is no LC tank circuit to smooth the sine wave output, the oscillator must be operated in Class A service on the linear operating region for the transistor.

You will have an opportunity to work with an RC oscillator type circuit when you use the NIDA oscillator as part of your job program for this lesson.

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PROGRESS CHECK
LESSON 2

RC Phase Shift Oscillators

TERMINAL OBJECTIVE(S):

32.2.57 When the student completes this lesson, (s)he will be able to TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in RC phase-shift oscillator circuits when given a training device, prefaulted circuit board, necessary test equipment, schematic diagrams and instructions. 100% accuracy is required.

ENABLING OBJECTIVE(S):

When the student completes this lesson, (s)he will be able to:

32.2.57.1 IDENTIFY the factors required to sustain oscillations in an LC or RC oscillator circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.57.2 IDENTIFY the basic principles by which phase shift is accomplished in an RC phase-shift network by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.57.3 IDENTIFY the function of components and circuit operation of an RC phase-shift oscillator circuit, given a schematic diagram, by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.57.4 IDENTIFY the methods by which the frequency of an RC phase-shift oscillator can be changed by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.57.5 IDENTIFY the advantages of an RC phase-shift oscillator by selecting the correct description of its characteristics from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON 2

RC Phase Shift Oscillator

1. One purpose of an LC tank and RC network is to cause _____ phase shift.

   a. 60 degrees
   b. 120 degrees
   c. 180 degrees
   d. 360 degrees

2. To sustain oscillation, the feedback of an oscillator circuit must be

   a. neutral.
   b. degenerative.
   c. regenerative.
   d. compounded.

3. Oscillator feedback is required to

   a. compensate for internal circuit power losses.
   b. provide damping for the oscillator.
   c. provide a forward bias for the transistors.
   d. compensate for circuit overloads.

4. The theoretical maximum amount of phase shift possible with a single RC network is almost

   a. 60 degrees.
   b. 90 degrees.
   c. 180 degrees.
   d. 360 degrees.

5. In order to cause a 180 degree phase shift, a practical minimum of ______ RC networks is needed.

   a. two
   b. three
   c. four
   d. five

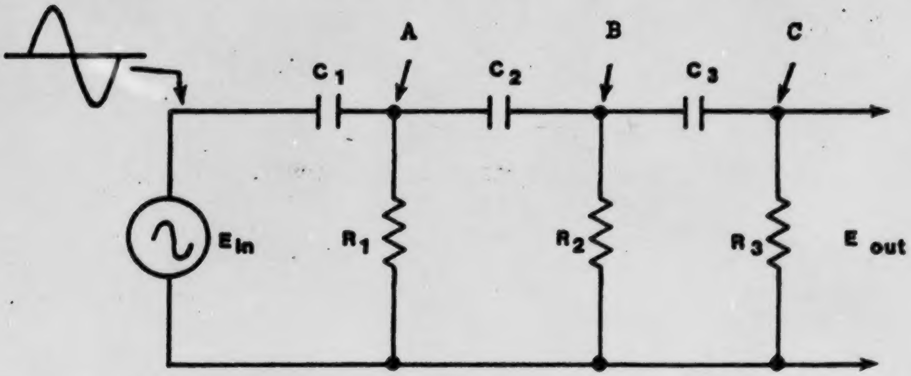
6. When series-connected RC networks are used to effect a phase shift, the total shift is the ______________ of the individual network phase shifts.

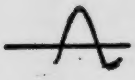
   a. product
   b. difference
   c. square
   d. sum

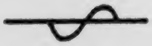
7. The phase shift of an individual RC network depends on the ____________.

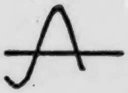
   a. values of R and C.
   b. reactance of R.
   c. resistance of C.
   d. amplitude of input signal.

REFER TO THE SCHEMATIC SHOWN BELOW WHEN ANSWERING QUESTIONS 8, 9 AND 10.




1.


2.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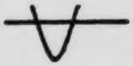

4.

8. With the input waveform shown, the output waveform is

   a. 1
   b. 2
   c. 3
   d. 4

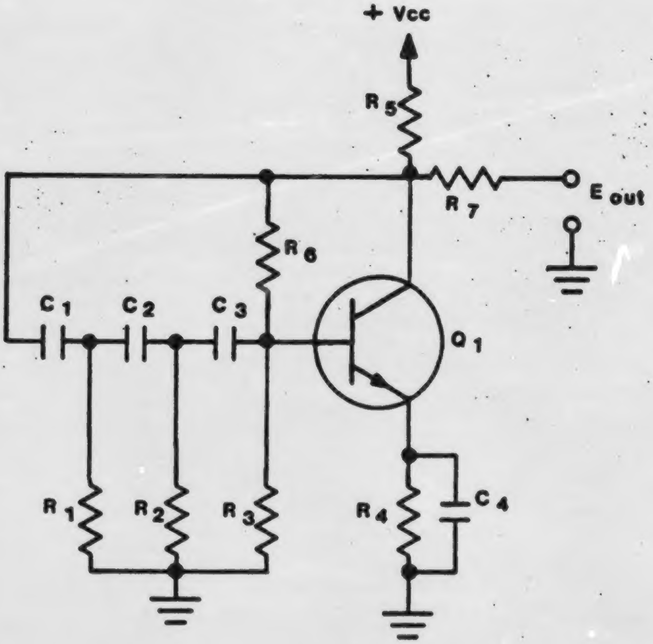
9. The signal at point A is represented by the waveform shown by

   a. 1
   b. 2
   c. 3
   d. 4

10. When the value of C2 is doubled, the output frequency

    a. increases.
    b. decreases.
    c. doubles.
    d. stays the same.

REFER TO THE SCHEMATIC SHOWN BELOW WHEN ANSWERING QUESTIONS 11, 12 AND 13.



11. The phase shift of each of the RC networks is theoretically about

    a. 45 degrees.
    b. 60 degrees.
    c. 90 degrees.
    d. 135 degrees.

12. The phase shift provided by transistor Q1 is

    a. 60 degrees.
    b. 90 degrees.
    c. 135 degrees.
    d. 180 degrees.

13. What type of feedback is provided to the base of Q1?

    a. neutral
    b. degenerative
    c. regenerative
    d. 60 degrees out of phase

14. The output frequency of an RC phase shift oscillator may be increased by ________________ the value of the resistors.

    a. averaging
    b. decreasing
    c. increasing
    d. squaring

15. RC phase shift oscillators provide a stable fixed frequency sine-wave output signal in the __________ to ________________ range.

    a. 15 Hz to 200 kHz
    b. 300 kHz to 700 kHz
    c. 800 kHz to 1.5 MHz
    d. 1000 MHz to ∞

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

JOB PROGRAM
FOR
LESSON 2

RC Phase Shift Oscillator

INTRODUCTION:

The purpose of this Job Program is to familiarize you with the operation of the RC Phase Shift Oscillator and to let you prove to yourself the principles you studied in the summary, narrative, or programmed instruction. As you know, in order to measure phase shift on an oscilloscope, you must trigger the oscilloscope sweep with an external signal. The "external sync" is used as a reference signal for the oscilloscope and the other signal compared with it.

TERMINAL OBJECTIVE(S):

32.2.57 When the student completes this lesson, (s)he will be able to TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in RC phase-shift oscillator circuits when given a training device, prefaulted circuit board, necessary test equipment, schematic diagram, and instructions. 100% accuracy is required.

ENABLING OBJECTIVE(S):

When the student completes this lesson, (s)he wll be able to:

32.2.57.6 MEASURE and COMPARE output waveforms and voltages of RC phase-shift oscillator circuits, given a training device, circuit boards, test equipment and proper tools, schematic diagrams, and a job program containing reference data for comparison. Recorded data must be within limits stated in the job program.

SAFETY PRECAUTIONS:

Observe all standard safety precautions. Beware of all exposed connections. An energized circuit may have dangerous voltages present.

EQUIPMENT REQUIRED:

1. NIDA 203 Audio Oscillator
2. NIDA 203-3 PCB-RC Phase Shift Oscillator
3. NIDA 207 Oscilloscope
4. AN/USM-207 Frequency Counter
5. BNC-BNC Cables (2)
6. 1X Probe (1)
7. BNC "TEE" Connector (1)
8. Schematic Diagram of the RC Phase Shift Oscillator

PROCEDURES:

1. Energize and set up the oscilloscope for dual trace operation with the trigger source switch set to the "EXT" position.

2. Connect the "TEE" connector to the trigger source input jack, connect a BNC cable from the output of the Audio Oscillator to one end of the "TEE" connector. Connect the second BNC cable from the "TEE" connector to the channel #1 input of the oscilloscope. This procedure will synchronize the scope and at the same time, permit viewing of the output waveform from the Phase Shift Oscillator on trace "1".

3. Connect the 1X probe to the channel #2 input of the oscilloscope.

4. Remove the top cover from the NIDA 203 Audio Oscillator.

5. Insert PCB 203-3 into the NIDA 203 Oscillator chassis.

6. Plug in and energize the NIDA 203 Audio Oscillator. A signal should appear on the channel #1 line of the oscilloscope. If it does not, turn the AMPLITUDE control slightly CW.

7. Set the TIME/DIV switch on the oscilloscope to .5 msec.

8. Connect the 1X probe to pin #7 of the PCB. Notice that the output from pin #7 is 180 degrees out of phase with the output from the Audio Oscillator. This is because the signal is shifted 180° by an amplifier in the Audio Oscillator before it reaches the output jack on the front panel.

9. Make the following calculations of the waveform shown on the channel #2 sweep.

   a. Calculate the amplitude of the waveform ____________ V p-p.

   b. Calculate the period of one cycle of the output waveform __________ msec.

   c. Calculate the output frequency ________________ Hz.

10. Plug in and energize the AN/USM-207 Frequency Counter. Allow a minimum of 5 minutes for warm up time.

11. Set the TIME BASE switch to 10^5.

12. Set the FUNCTION switch to its maximum CCW position.

13. Set the B MULTIPLIER switch to position "1".

14. Disconnect the Audio Oscillator cable from the "TEE" connector and connect it to the "B" AC input jack on the counter. This connection permits "period measurement" of the oscillator frequency. Remove the probe from pin #7 since this probe causes inaccurate readings on the frequency counter through the scope.

15. On the Audio Oscillator, turn the amplitude control fully CW.

16. Turn the AN/USM-207 power on switch to "TRACK".

17. Turn the "B" TRIGGER VOLTS control until a reading appears on the frequency counter. Allow sufficient time for the reading to stabilize.

NOTE: This is a very sensitive control. If you turn it too far CW the frequency counter will indicate zero because you are overdriving the counter. If you do not turn it far enough the counter will indicate zero because the signal is not of sufficient amplitude to start the count. The gate lamp will be your guide. If the lamp starts to flash on and off a reading should appear on the counter. Manipulate this control to prove this to yourself.

  a. What is the period of the input waveform? _________ msec.

  b. Does this agree with step #9b above? __________ yes/no.

18. Set the TIME BASE switch to the "1" position.

19. Set the FUNCTION switch to the FREQ position.

20 Remove the BNC connector from the "B" AC input jack and connect it to the "C" AC input jack.

21. Set the "C" MULTIPLIER switch to position "1".

22. Set the SENSITIVITY switch to the "FREQ C" position.

23. Turn the "C" TRIGGER VOLTS control until a reading appears on the frequency counter. Refer to the NOTE in step #17.

  a. What is the frequency of the input waveform? __________ Hz.

  b. Does this agree with step #9c above __________ yes/no.

24. Deenergize the AN/USM-207 frequency counter. Remove the BNC connector from the "C" AC input and connect it to the "TEE" connector on the oscilloscope.

25. Manipulate the VOLTS/DIV controls and the VARIABLE VOLTS/DIV controls on channel #1 and channel #2 for equal amplitude signals with the 1X probe connected between R4 and R7. Notice that these two waveforms are 180° out of phase.

NOTE: Remember again that the reference waveform is applied to channel #1 and that the amplitude and phase of this waveform will not change. The waveform you wish to observe is applied to channel #2 and this is the waveform you must expect to change in amplitude and in phase.

26. Using the channel #1 and channel #2 vertical position controls combine the two waveforms into a single waveform.

27. Connect the 1X probe to the junction of C3 and R6.

    a. What has happened to the amplitude? ___________.

    Notice that the voltage applied to channel #2 is leading the reference voltage by 60 degrees.

28. Connect the 1X probe to the junction of C2 and R5.

    a. What has happened to the amplitude? ___________.

29. Change the channel #2 VOLTS/DIV control to increase the amplitude.

    Notice that the voltage applied to channel #2 is leading the reference voltage by 120 degrees.

30. Connect the 1X probe to the junction of C1 and R2.

    a. What has happened to the amplitude? _________.

    Notice that the voltage applied to channel #2 is almost in phase with the reference voltage and is the regenerative feedback necessary to keep the circuit oscillating.

You have now completed the Job Program for Module Thirty Two, Lesson 2. You have seen the operation of the RC Phase Shift Oscillator, calculated and measured the output frequency. If you do not understand any part of this Job Program it is suggested that you go through the parts that you do not understand.

CHECK YOUR RESPONSES TO THIS JOB PROGRAM WITH THE ANSWER SHEET. IF YOUR RESPONSES AGREE WITH THE ANSWER SHEET, YOU MAY TAKE THE LESSON TEST. IF YOUR RESPONSES DO NOT AGREE, OR IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THIS JOB PROGRAM, REVIEW THE PROCEDURES OF THIS PROGRAM, ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS, OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOUR RESPONSES DO AGREE.

60

FAULT ANALYSIS

(PAPER TROUBLESHOOTING)

FOR

MODULE 32, LESSON 2

NOW THAT YOU HAVE COMPLETED THE KNOWLEDGE SECTION OF THIS LESSON, YOU ARE READY FOR PAPER TROUBLESHOOTING.

THE COMPUTER WILL ASSIGN YOU A SET OF PAPER TROUBLESHOOTING PROBLEMS ON RC PHASE-SHIFT OSCILLATORS. THESE PROBLEMS WILL HELP YOU DEVELOP THE MENTAL SKILLS REQUIRED IN ACTUAL TROUBLESHOOTING. YOU WILL BE GIVEN SYMPTOMS OF A FAILURE AND CIRCUIT MEASUREMENTS THAT WILL ALLOW YOU TO IDENTIFY THE PROBLEM.

AFTER YOU COMPLETE THE PAPER TROUBLESHOOTING SECTION, THE COMPUTER WILL ASSIGN YOU A PRACTICE TROUBLESHOOTING PROBLEM ON A FAULTY PRINTED CIRCUIT BOARD.

REMEMBER THAT REFERENCE VOLTAGES, WAVEFORMS, AND A SCHEMATIC ARE CONTAINED IN THIS STUDENT GUIDE FOR YOUR USE IN BOTH PAPER AND ACTUAL TROUBLESHOOTING PROBLEMS.

TERMINAL OBJECTIVE:

32.2.57 When the student completes this lesson, (s)he will be able to TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in RC phase-shift oscillator circuits when given a training device, prefaulted circuit board, necessary test equipment, schematic diagrams and instructions. 100% accuracy is required.

ENABLING OBJECTIVE(S):

When the student completes this lesson, (s)he will be able to:

32.2.57.7 IDENTIFY the faulty component or circuit malfunction in a given RC phase-shift oscillator circuit, given schematic diagrams and failure symptoms, by selecting the correct fault from a choice of four. 100% accuracy is required.*

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*This objective is considered met upon successful completion of the terminal objective.

INFORMATION SHEETS
FOR
TROUBLESHOOTING PERFORMANCE TEST

INTRODUCTION:

Using the following six step troubleshooting procedure will aid you in determining which component is faulty. In the split method of troubleshooting, the collector of Q1 has been selected as the starting point for this performance test. Based on your interpretation of the scope presentation at this point, you can determine which direction you should go.

EQUIPMENT:

1. NIDA 203 Transceiver Trainer
2. NIDA PCB 203-3 Phase Shift Oscillator
3. NIDA 207 Oscilloscope
4. Simpson 260 Multimeter and Test Leads
5. BNC-BNC Cables (2 short)
6. 1X Probe
7. TEE Connector (1)

INSTRUCTIONS:

1. Each student is required to determine the defective component in a prefaulted Phase Shift Oscillator. Your six step troubleshooting sheet must indicate that you used accurate test measurements and a logical procedure to find the faulty component.

2. Standard test equipment will be available to you in the form of an oscilloscope and a Simpson 260 multimeter. You will be expected to observe all safety precautions throughout the test. A safety violation will result in an automatic failure of the performance test. In that event you will be counselled and given remedial training.

3. You will take a numbered position in the test room. After briefing by the Learning Supervisor you will fill out the heading of the troubleshooting form. On a signal from the Learning Supervisor you will then start the test. If at any time during the test you should require assistance, raise your hand. DO NOT LEAVE YOUR POSITION. A Learning Supervisor will assist you with your trouble. If the trouble is due to no fault of your own, you will not be penalized and a time extension will be given if necessary. You will set up the equipment according to the specifications given in the Job Program.

TROUBLESHOOTING PERFORMANCE TEST

4. You must identify the faulty component to pass this performance test.

5. If you do not understand these instructions, raise your hand and ask your Learning Center Instructor. If you do understand these instructions and upon a signal from your Learning Center Instructor you may now begin the Performance Test on the next page.

TROUBLESHOOTING PERFORMANCE TEST

DIRECTIONS: DO NOT WRITE IN THE PERFORMANCE TEST BOOKLET. MAKE ALL YOUR RESPONSES ON THE SIX STEP TROUBLESHOOTING SHEET SUPPLIED WITH THIS TEST PACKET. THIS PERFORMANCE TEST BOOKLET IS DESIGNED TO AID YOU IN COMPLETING THE STANDARD SIX STEP TROUBLESHOOTING FORM. COMPLETE THE STEPS USING YOUR KNOWLEDGE AND SKILL OF THE CIRCUIT SHOWN. CONTACT YOUR LEARNING CENTER INSTRUCTOR IF YOU HAVE ANY QUESTIONS.

SET UP THE EQUIPMENT AS YOU WERE INSTRUCTED IN THE JOB PROGRAM. CONNECT THE "TEE" CONNECTOR TO THE TRIGGER SOURCE ON THE OSCILLOSCOPE. CONNECT ONE BNC CABLE FROM THE OUTPUT OF THE PHASE SHIFT OSCILLATOR AND ONE END OF THE "TEE" CONNECTOR. CONNECT THE SECOND BNC CABLE FROM THE "TEE" CONNECTOR TO THE CHANNEL #1 INPUT OF THE OSCILLOSCOPE. CONNECT THE PROBE TO THE CHANNEL #2 INPUT OF THE SCOPE. ALL VOLTAGES AND WAVEFORMS WILL BE MADE WITH REFERENCE TO GROUND UNLESS THE PCB IS REMOVED TO MEASURE FRONT TO BACK RESISTANCE RATIOS OR TO MEASURE THE RESISTANCE OF A SPECIFIC RESISTOR.

STEP ONE - SYMPTOM RECOGNITION

1. Does the equipment energize? ____________ yes/no

STEP TWO - SYMPTOM ELABORATION

1. NO METERS. Proceed to step #3.

STEP THREE - LIST THE PROBABLE FAULTY FUNCTION(S)

1. There is only one function - Proceed to Step #4.

STEP FOUR - LOCALIZE THE FAULTY FUNCTION

1. Feedback network, phase shifting network, transistor.
2. Verify the faulty function by use of test equipment.
3. List the test points where voltages were obtained.
4. Reference voltages and waveforms are listed in the voltage/waveform chart.
5. Be sure you list the reference voltage/waveform on the troubleshooting sheet for each measurement you make.

TROUBLESHOOTING PERFORMANCE TEST

STEP FIVE - LOCALIZE THE FAULTY CIRCUIT/COMPONENT

1. List the test points where actual voltages were taken.
2. What circuit/component in the faulty function listed in step four is faulty?
3. If you have determined the faulty circuit but not the faulty component proceed to step six.

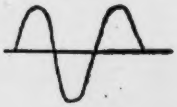
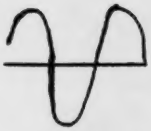
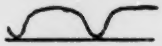
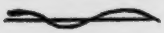
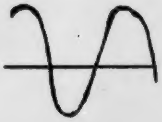
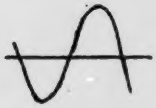
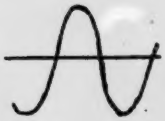
STEP SIX - FAILURE ANALYSIS

1. Secure the power and using the Simpson 260 take resistance measurements.
   a. Check front-to-back ratios on the transistor.
   b. Continuity checks on printed circuit board foil.
   c. Capacitors can be shorted or open.
   d. Resistors can be open.
2. Explain in your own words why the component listed in steps five or six above would cause the symptoms listed in steps one and two of the six step troubleshooting procedure? Write your answer in the space provided on the troubleshooting form.

TAKE YOUR SIX STEP TROUBLESHOOTING SHEET TO YOUR LEARNING CENTER INSTRUCTOR FOR VERIFICATION AND EVALUATION.

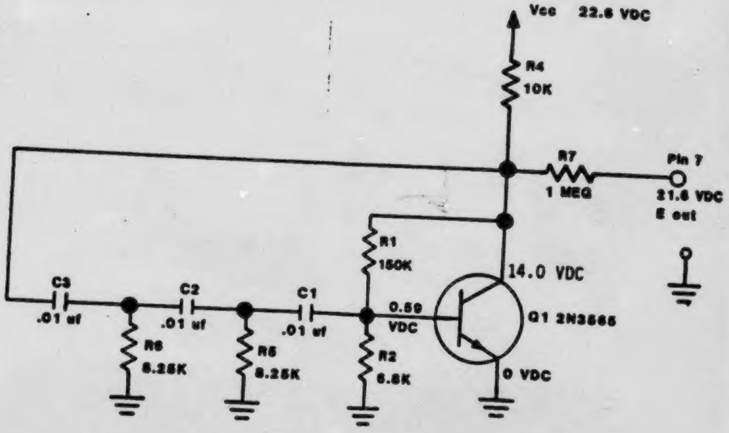
VOLTAGE/RESISTANCE/WAVEFORM CHART

The following Voltages, Resistances and Waveforms were taken with a Simpson 260 multimeter and an Oscilloscope with the 1X probe connected to the channel #2 input. All Voltages, Resistances, and Waveforms were taken with respect to ground or circuit common.

Point of Check	Voltage	Resistance	Waveforms	
Pin #7	20 VDC	860 K ohms		0.190 V P/P
V_C Q1	17 VDC	220 K ohms		4 V P/P
V_B Q1	0.55 VDC	930 ohms		0.045 V P/P
Pin #6	21.7 VDC	240 K ohms		0.01 V P/P
Junction R6 & C3	0 VDC	8.5 K ohms		1.45 V P/P
Junction R5 & C2	0 VDC	8.5 K ohms		0.5 V P/P
Junction R2 & C1	0.55 VDC	930 ohms		0.045 V P/P

SCHEMATIC DIAGRAM

RC PHASE SHIFT
OSCILLATOR
PCB 203-3

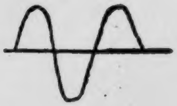
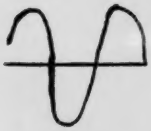
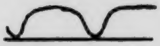
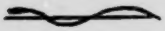
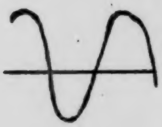
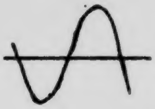
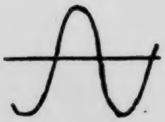

Vcc 22.6 VDC
R4 10K
R7 1 MEG
Pin 7
21.6 VDC
E out
R1 150K
14.0 VDC
0.59 VDC
Q1 2N3565
0 VDC
C3 .01 uf
C2 .01 uf
C1 .01 uf
R6 8.25K
R5 8.25K
R2 6.8K

RC PHASE SHIFT OSCILLATOR

P.P. 51-52

VOLTAGE/RESISTANCE/WAVEFORM CHART

The following Voltages, Resistances and Waveforms were taken with a Simpson 260 multimeter and an Oscilloscope with the 1X probe connected to the channel #2 input. All Voltages, Resistances, and Waveforms were taken with respect to ground or circuit common.

Point of Check	Voltage	Resistance	Waveforms	
Pin #7	20 VDC	860 K ohms		0.190 V P/P
V_C Q1	17 VDC	220 K ohms		4 V P/P
V_B Q1	0.55 VDC	930 ohms		0.045 V P/P
Pin #6	21.7 VDC	240 K ohms		0.01 V P/P
Junction R6 & C3	0 VDC	8.5 K ohms		1.45 V P/P
Junction R5 & C2	0 VDC	8.5 K ohms		0.5 V P/P
Junction R2 & C1	0.55 VDC	930 ohms		0.045 V P/P

SUMMARY
LESSON 3

Wien-Bridge Oscillator

In your previous study of oscillators you learned how the Hartley oscillator and the RC Phase shift oscillator accomplished 360° of phase shift. Remember that this phase shift is necessary in order to provide regenerative feedback to initiate and sustain oscillation.

The Wien-bridge oscillator also requires 360° of phase shifting. With the Wien-bridge oscillator, the phase shift is provided by two amplifiers. Each amplifier accomplishes 180° of phase shift.

The bridge portion of the oscillator determines the output frequency and maintains a constant output amplitude. Figure 1 shows the schematic of the bridge circuit together with block diagrams for the two amplifiers which make up the remainder of the Wien bridge circuit.

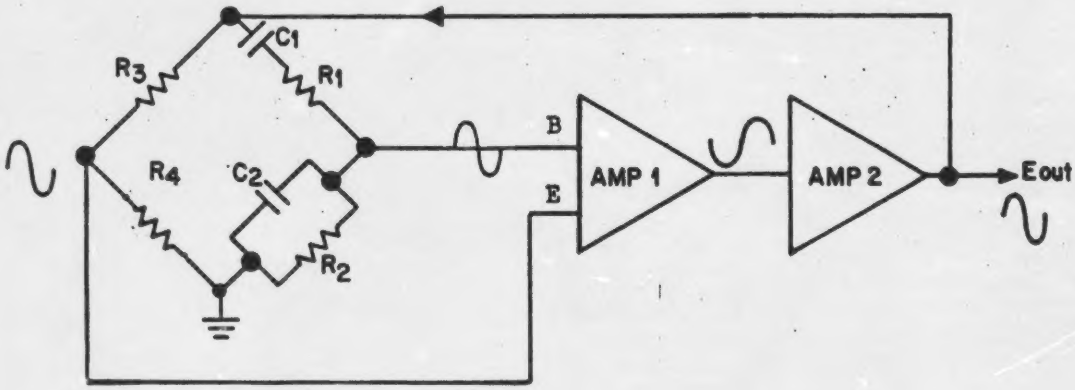


Figure 1

WIEN-BRIDGE OSCILLATOR BLOCK DIAGRAM

Frequency selection in the Wien-bridge oscillator is the result of the resistive-reactive bridge circuit comprised of capacitors C_1 and C_2 and R_1 and R_2. The output of this circuitry is a single frequency, with zero degree phase shift and maximum amplitude. All other frequencies are effectively eliminated. The regenerative output from the bridge circuit is applied to the base of the transistor in the first stage of amplification.

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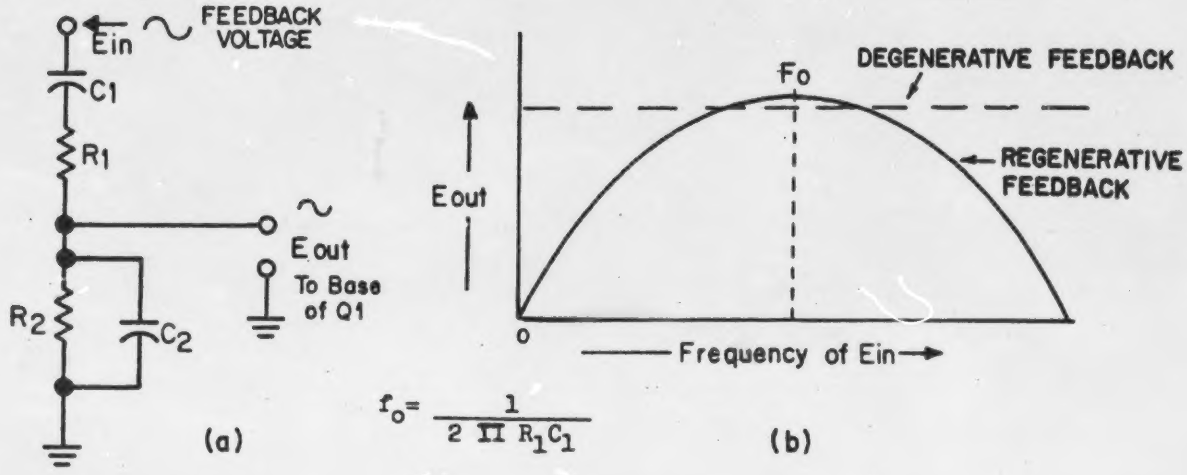
The remaining components of the bridge circuit, namely, R_3 and R_4 form a voltage divider which provides a degenerative voltage. The output of this circuit is applied to the emitter of the transistor in the first amplifier. Because this voltage is applied to the emitter it opposes the regenerative voltage applied to the transistor's base. Circuit oscillation occurs only when the regenerative feedback voltage exceeds the degenerative feedback voltage. The out of phase degenerative feedback voltage acts to regulate the amplitude of the output voltage and improves the purity of the output waveform. Changes in the amplitude of the output signal are automatically compensated for by the degenerative portion of the bridge ciruit. This is necessary to maintain the output amplitude at a constant level.

Figure 2 shows the schematic for the frequency determining network of the Wien-bridge oscillator together with a drawing which shows the relationship of the output voltage amplitude to the frequency of oscillator operation.



$$f_o = \frac{1}{2\pi R_1C_1}$$

Figure 2

FREQUENCY DETERMINING NETWORK

The frequency of the oscillator is determined by the formula $1 \div 2\pi R_1C_1$, where $R_1 = R_2$ and $C_1 = C_2$. In this example, and in many Wien-bridge oscillators, R_1 and R_2 are equal value resistors and C_1 and C_2 are equal value capacitors. The output frequency of the oscillator may be changed by increasing or decreasing the resistance or capacitance of R or C in the frequency determining portion of the bridge. At frequencies below the oscillator frequency, the output amplitude of the RC network is less than the output amplitude at the frequency of operation. This is due to the high reactance of C1. At one frequency the reactance of C_1 and C_2 compensate for each other. This leaves only the resistance of R_1 and R_2. At this frequency, the circuit is purely resistive, no phase shift occurs, with the result that the output voltage is at maximum and is greater than the degenerative voltage.

Refer to the right hand side of Figure 2 and notice that when the output frequency is at the oscillator frequency, the regenerative voltage is greater than the degenerative voltage. Notice also that the degenerative voltage is shown by the dotted line. When the circuit operates at Fo, a maximum regenerative feedback voltage is provided. Because this feedback is greater than the degenerative feedback, oscillation occurs and is sustained. At frequencies above the oscillator frequency (Fo), the reactance values are reduced and C_2 becomes the controlling reactance. Recall that in a parallel circuit, the smaller resistance or reactance controls the circuit. Therefore, since the reactance of C_2 controls the parallel combination of R_2-C_2, this causes the output voltage to be less than that at the frequency of operation.

The drawing shown in Figure 3 shows a redrawn version of the Wien bridge circuit together with block diagrams for the two amplifiers which are part of the total circuit.

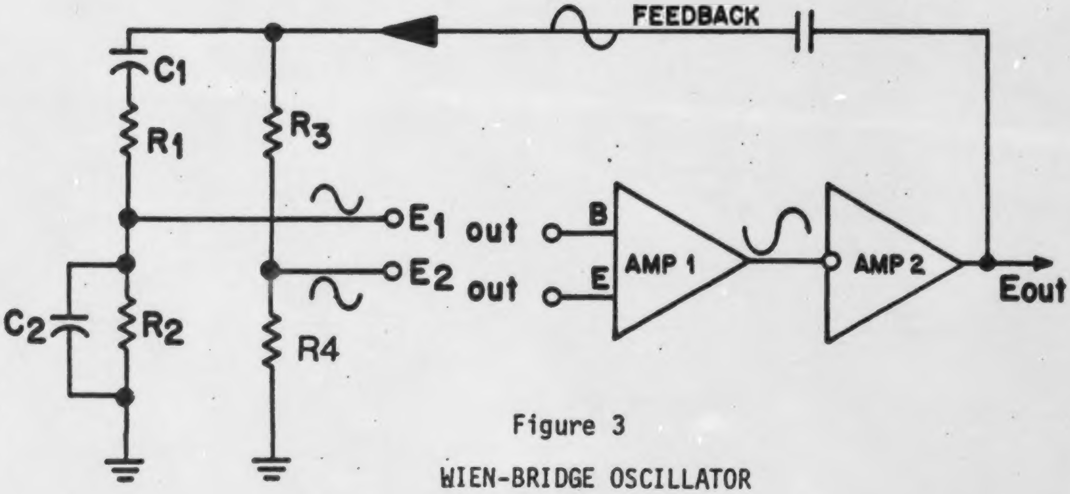


Figure 3

WIEN-BRIDGE OSCILLATOR

The two outputs of the bridge circuit are identified as E_1 out and E_2 out. E_1 is the output from the frequency determining section of the bridge circuit and this regenerative output is applied to the base of the first amplifier. E_1 is the output from the voltage divider, is degenerative, and applied to the emitter of the first amplifier stage.

The schematic shown in Figure 4 is that of a complete Wien bridge circuit.

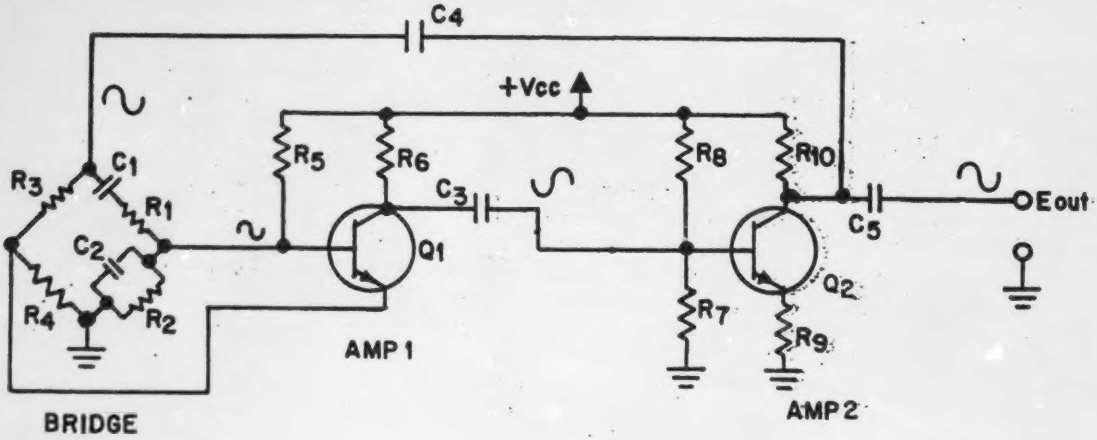


Figure 4

WIEN-BRIDGE OSCILLATOR

In addition to the bridge circuit, the two amplifier circuits which accomplish the 360° phase shift are shown. Notice that waveforms are also indicated on the schematic. Both of the amplifiers in this circuit are biased to operate in Class A service. Recall that this class of operation causes the transistor to conduct during the entire input cycle and produces a distortion-free output. Notice particularly that the regenerative feedback is connected to the base of Q_1 and the degenerative feedback is connected to the emitter of the transistor. Recall also that the degenerative feedback opposes the regenerative feedback applied to the transistor's base.

The function of the amplifier stage components is as follows: Forward bias for transistor Q_1 is provided by voltage divider R2/R5, while R7/R8 perform the same function for Q_2. R6 and R10 act as collector load resistors while R4 and R9 are emitter resistors for Q_1 and Q_2 respectively. C3 functions as the inter-stage coupling capacitor and C5 is the output coupling capacitor. C4 is the feedback capacitor which couples a portion of the output signal back to the bridge circuit.

PROGRESS CHECK

LESSON 3

Wien-Bridge Oscillator

TERMINAL OBJECTIVE(S):

32.3.58 When the student completes this lesson, (s)he will be able to IDENTIFY the schematic diagrams, component functions, and operational principles of various Wien-bridge oscillator circuits, including the accomplishment of phase shift, regenerative and degenerative feedback, frequency variation, and automatic gain control, by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVE(S):

When the student completes this lesson, (s)he will be able to:

32.2.58.1 IDENTIFY the advantageous characteristics of, and typical applications for, a Wien-bridge oscillator by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.58.2 IDENTIFY the sections of a Wien-bridge oscillator which accomplish phase shift and frequency selection by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.58.3 IDENTIFY the components of a Wien bridge which provide degenerative and regenerative feedback by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.58.4 IDENTIFY the relative amplitudes of the two outputs of a Wien bridge at various frequencies, given a schematic diagram showing the sizes of components, by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.58.5 IDENTIFY the methods by which the frequency of a Wien-bridge oscillator may be changed by selecting the correct statement from a choice of four. 100% accuracy is required.

32.2.58.6 IDENTIFY the function of components and circuit operation of fixed-frequency, variable-frequency and AGC-type Wien-bridge oscillator circuits, given a schematic diagram, by selecting the correct statement from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON THREE

Wien-Bridge Oscillator

1. Wien-bridge oscillator circuits are used most frequently with:

   a. test and laboratory equipment.
   b. power and amplifier equipment.
   c. voltage multipliers and transmission equipment.
   d. RC networks and tank circuits.

2. The Wien-bridge oscillator has the advantage of:

   a. variable frequency with a stable sawtooth output waveform.
   b. constant amplitude with a variable sawtooth output waveform.
   c. variable pulse output waveform with a constant amplitude.
   d. constant amplitude output with excellent frequency stability.

3. The 360° phase shift of a Wien-bridge oscillator is the result of ______________________ action.

   a. RC network
   b. tank circuit
   c. amplifier
   d. rectifier

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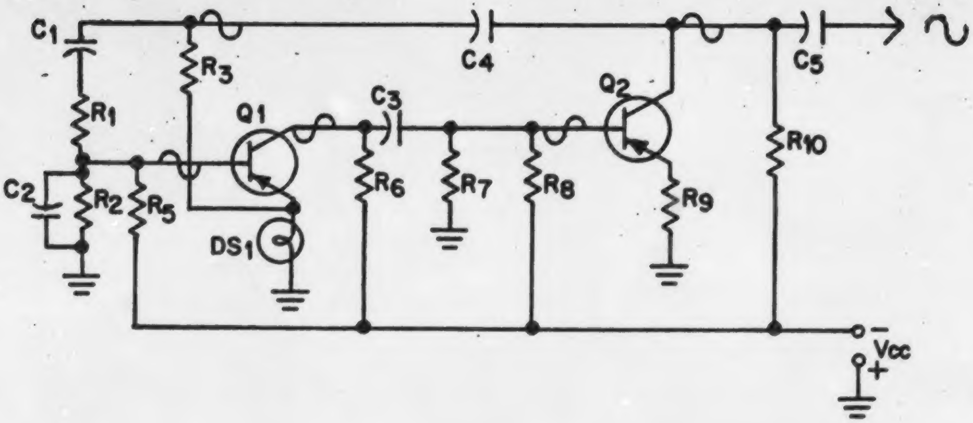
REFER TO THE SCHEMATIC SHOWN BELOW WHEN ANSWERING QUESTIONS 4 AND 5.


C1
R3
C4
C5
Q2
C3
Q1
R1
R10
C2
R2
R5
R6
R7
R8
R9
DS1
–
Vcc
+

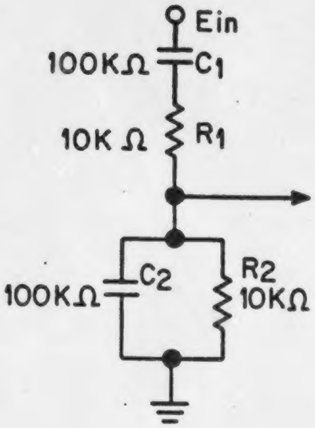
4. The frequency of the oscillator is determined by a(n)

   a. transformer.
   b. LC tank.
   c. resistive-capacitive bridge.
   d. inductive-capacitive bridge.

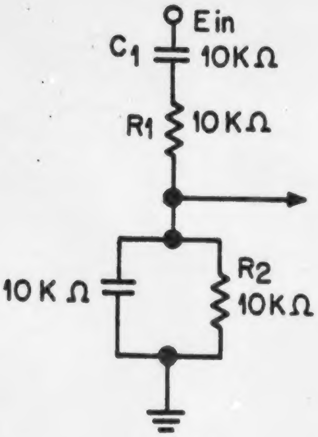
5. The output frequency of the oscillator may be increased by _______________ the resistance of _________________.

   a. increasing, R3 and R4
   b. decreasing, R3 and R4
   c. increasing, R1 and R2
   d. decreasing, R1 and R2

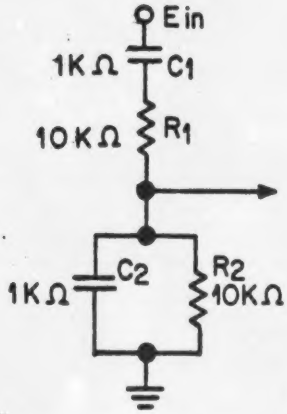
REFER TO THE SCHEMATICS BELOW WHEN ANSWERING QUESTION 6.


Ein
100KΩ
C1
10K Ω
R1
C2
100KΩ
R2
10KΩ

(1)


Ein
C1
10KΩ
R1
10KΩ
10K Ω
R2
10KΩ

(2)

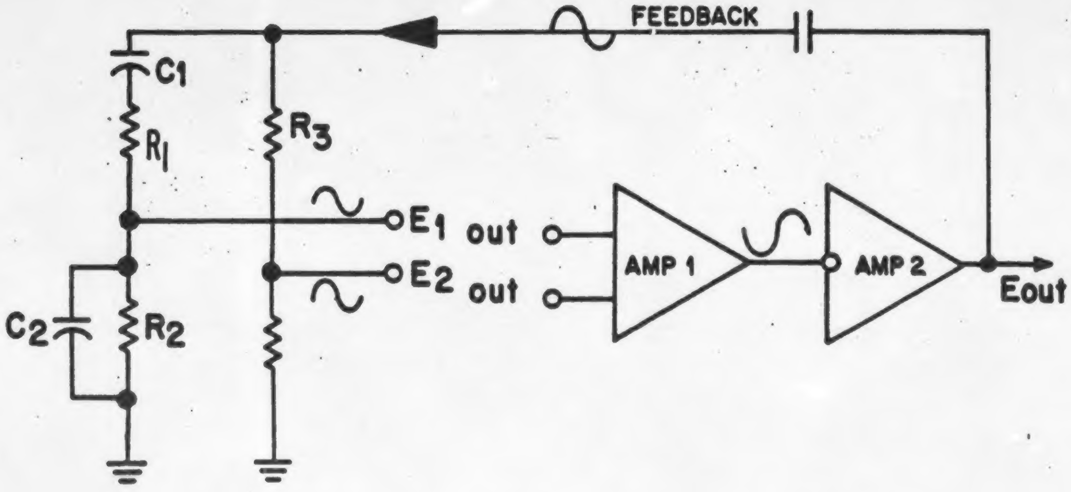

Ein
1KΩ
C1
10KΩ
R1
C2
1KΩ
R2
10KΩ

(3)

6. The circuit which provides the maximum AC output voltage is

a. 1
b. 2
c. 3

REFER TO THE DRAWING SHOWN BELOW WHEN ANSWERING QUESTIONS 7 AND 8.


FEEDBACK
C1
R1
R3
E1 out
E2 out
C2
R2
AMP 1
AMP 2
Eout

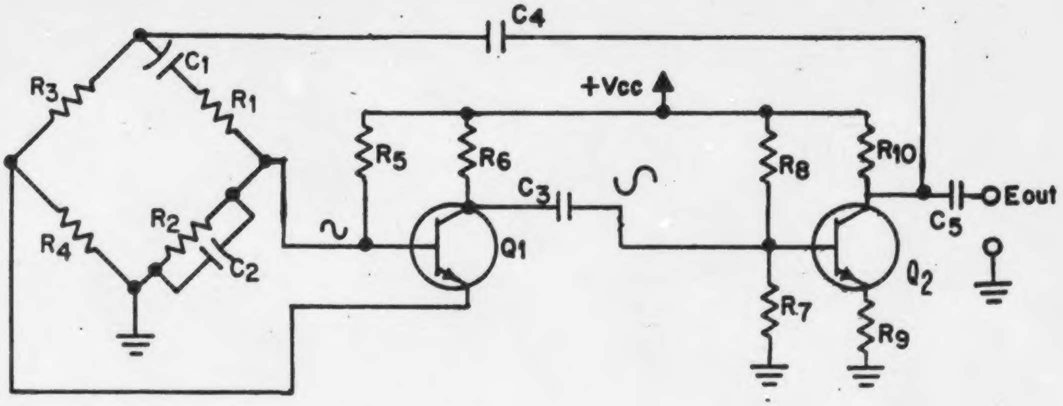
7. The output at E1 is ______________________ and is applied to the ____________________ of the first amplifier stage.

   a. degenerative, emitter
   b. regenerative, emitter
   c. degenerative, base
   d. regenerative, base

8. The output at E2 is _______________ and is applied to the ________ ______________ of the first amplifier stage.

   a. regenerative, emitter
   b. degenerative, emitter
   c. regenerative, base
   d. degenerative, base

REFER TO THE OSCILLATOR SCHEMATIC SHOWN BELOW WHEN ANSWERING QUESTIONS 9 AND 10.



9. The output frequency of the oscillator is determined by

   a. R1, R2, C1, and C2.
   b. R3, R4, R6, and Q1.
   c. R3 and R4.
   d. Q1, Q2, and R10.

10. Automatic gain control (AGC) may be provided by substituting a thermistor or tungsten filament lamp for:

   a. Q1
   b. R5
   c. R4
   d. R3

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

SUMMARY
LESSON 4

Blocking Oscillator

When you studied oscillators previously, you learned about oscillators that provide sine-wave outputs. The blocking oscillator is a special type of oscillator that produces a short duration, pulse output waveform. The pulse output waveform of the blocking oscillator is used in radar equipment, computers, and other equipment where timing is required. The blocking oscillator generates a very narrow output pulse.

There are a number of terms that you should become familiar with prior to proceeding with the lesson on blocking oscillators. These terms, listed below, are also used with radar equipment.

PULSE WIDTH (PW) Pulse width is the time from the start of the pulse to the end of the pulse.

PULSE REPETITION TIME (PRT) Pulse repetition time is the time from the start of one pulse to the start of the next pulse. It is measured from the leading edge of one pulse to the leading edge of the next pulse.

PULSE REPETITION FREQUENCY (PRF) Pulse repetition frequency refers to the frequency at which pulses occur. The frequency is usually stated in cycles per second.

PULSE REPETITION RATE (PRR) Pulse repetition rate is the number of pulses per second (PPS).

The blocking oscillator uses a special type of transformer. This transformer is constructed in such a way that it passes a square wave or pulse with a minimum amount of distortion. The transformer is called a pulse transformer. The schematic diagram for the pulse transformer is shown in Figure 1.

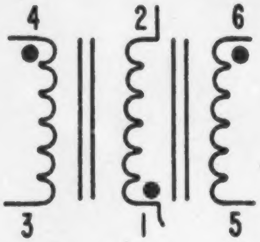


Figure 1

PULSE TRANSFORMER SCHEMATIC SYMBOL

The pulse transformer differs from other transformers in that it has two secondary windings. The second secondary winding is called a tertiatry winding. Tertiary means third. The three windings of the pulse transformer are wound on the same iron core in such a way that voltages are induced into both the secondary and tertiary windings simultaneously. Refer to the figure and notice that phasing dots are shown. Therefore, the voltage polarity of pins 1, 4, and 6 is identical. The pulse transformer is designed and constructed in a special way so it saturates at a low current level. Once the transformer is saturated, any futher increase in current through the primary has no effect on the secondary output voltage. This is necessary if the blocking oscillator is to function properly.

The schematic diagram shown in Figure 2 is that of a blocking oscillator.

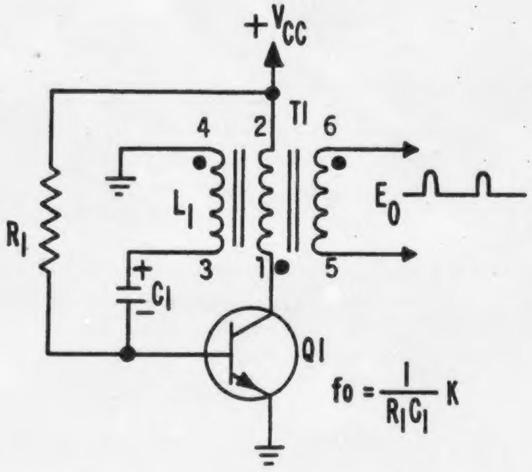


Figure 2

BASIC BLOCKING OSCILLATOR CIRCUIT

In may ways, this circuit is similar to the Armstrong oscillator circuit. The major difference between the two oscillator circuits is in the frequency determining circuitry. Whereas the frequency of the Armstrong oscillator is determined by a tank circuit, the blocking oscillator output frequency depends on the RC network made up of R1 and C1. In both cases, regenerative feedback is necessary in order to intiate and sustain oscillation. With the blocking oscillator, regenerative feedback is provided by the inductive coupling of the transformer's primary and secondary. Forward bias is provided by R1, which is connected between Vcc and the base of transistor Q1, to provide initial conduction of Q1.

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Refer again to the schematic shown in Figure 2. Because of the positive potential resulting from the action or R1, transistor Q1 is forward biased. As a result of this bias, when power is applied the transistor conducts. Since the resistance between the emitter and collector of Q1 is reduced, current now flows from ground through Q1, the primary of the transformer T1, and to Vcc. This results in a negative polarity at pin 1 and a positive polarity at pin 3 due to the transformer action. The positive signal from pin 3 is applied to the base of Q1 and increases the transistor's forward bias and the transistor conducts more. This action continues until the transistor or the pulse transformer reach the point of saturation. Since the pulse transformer is designed to saturate quite readily, the transformer reaches the point of saturation before the transistor.

At the same time current flows through Q1, capacitor C1 charges to a voltage equal to the secondary voltage of the pulse transformer. When the capacitor is fully charged, the current between the base and emitter of Q1 is reduced to a point where the transistor can no longer conduct. In effect, the transistor is cut off at this time. In other words, when the charge on capacitor C1 reaches maximum, the transistor cuts off.

The capacitor charge at this time is equal to the peak secondary voltage of the transformer's secondary (pin 3-4). At this time, since transistor conduction has stopped, the primary magnetic field of the transformer collapses. Remember from your study of inductors that an inductor opposes a change in current and therefore, in this case, the inductance will attempt to keep current flowing in the same direction. When the magnetic field of the transformer primary collapses, the voltage across capacitor C1 and transformer secondary (3 and 4) series aid each other and exceed the voltage at Vcc. Because the secondary voltage of the transformer is series aided by C1's voltage, the potential applied to the base of Q1 is now negative. At this time the transistor becomes reverse biased.

Q1 remains cut off, or blocked by this reverse bias until capacitor C1 discharges to a point where the voltage at Vcc exceeds C1's potential. Because a transistor is blocked for a significant amount of time during each cycle of operation, the circuit is called a blocking oscillator circuit. The time required for the capacitor to discharge is determined by the time constant resulting from the interaction of R1 and C1. If you have difficulty understanding how an RC network functions refer to Module 11. Eventually the capacitor discharges to a point where the positive Vcc voltage is again applied to the base of Q1. When this happens the transistor is again forward biased, it conducts and the transformer action produces regenerative feedback. The cycle repeats and repeats producing a pulsed type output.

The output waveform of the circuit across terminals 5 and 6 of the transformer is shown in Figure 3.

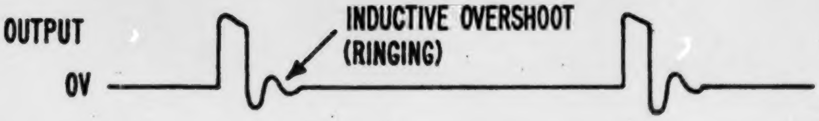

Figure 3

BLOCKING OSCILLATOR OUTPUT-TERTIARY WINDING

Examine the waveform and notice the inductive overshoot or ringing effect. This is an undesirable output resulting from the rapid current changes through the transformer windings. Because these damped oscillations may cause problems in other circuits associated with the blocking oscillator, it is necessary to eliminate this inductive overshoot or ringing.

One technique that is commonly used to eliminate the inductive overshoot or ringing, is to use clamping diodes as shown in Figure 4.

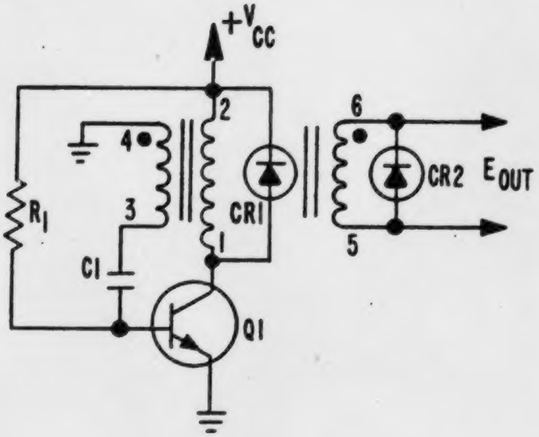

Figure 4

BLOCKING OSCILLATOR WITH CLAMPING DIODES

In this example, a clamping diode CR1 is placed directly across terminals 1 and 2 of the transformer's primary. When Q1 cuts off, the voltage across terminals 1 and 2 of the transformer reverses polarity, causing diode CR1 to become forward biased. Because diode CR1 has a low resistance when forward biased, the inductive overshoot voltage and the ringing is quickly damped out.

Another method often used for reducing the ringing is to connect a diode across the output winding of the pulse transformer. This is also shown in Figure 4. This diode, diode CR2, becomes forward biased whenever the output voltage at terminal 6 is negative in relation to terminal 5. Because of the diode action, the output is limited, or clamped, to within a few tenths of a volt. This results in an output waveform that is relatively free of inductive overshoot or ringing.

Another means of reducing the ringing action of the transformer is to use resistive loads commonly called dampers. In this case, small value resistors are placed in series or shunt with the transformer secondary or tertiary windings. Resistors used in this way absorb some of the oscillations caused by the rapid collapse of the transformer's magnetic field. It is also possible to use both resistors and clamping diodes. Circuit design characteristics determine whether clamping diodes and resistive loads are used together or independently.

The schematic diagram shown in Figure 5 is a slight variation of the basic blocking oscillator circuit. This is the schematic for the NIDA blocking oscillator which you will use and become familiar with when you complete the job program associated with this lesson.

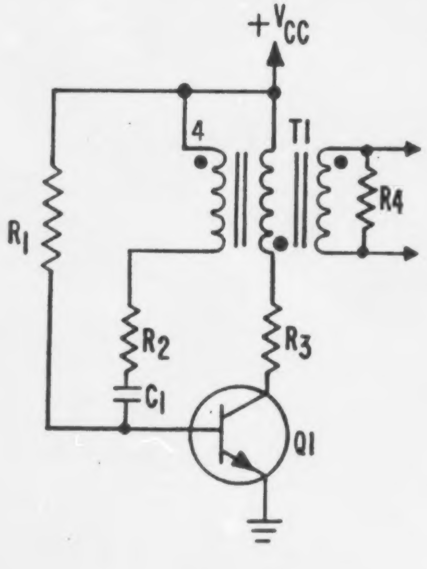

Figure 5

NIDA BLOCKING OSCILLATOR SCHEMATIC

The basic difference between this circuit and the blocking oscillator circuit which you previously studied is that terminal 4 of transformer T1 is returned to Vcc vice ground. An arrangement of this type removes the Vcc power source from the discharge path of the capacitor and improves the total stability of the circuit. Other than this difference, the operation of the NIDA blocking oscillator is essentially the same as a basic blocking oscillator circuit. In this case, notice that resistors R2, R3 and R4 function to dampen part of the undesirable oscillation of the transformer resulting from rapid current variation.

There are several variations of the basic circuit; for example, triggered, synchronized, divided (count-down) versions of the oscillator circuit. The basic distinction between these circuits and the basic circuit is that the variations require input triggers.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 4

Blocking Oscillators

TERMINAL OBJECTIVE(s):

32.4.59 When the student completes this lesson, (s)he will be able to TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in blocking oscillator circuits when given a training device, prefaulted circuit board, necessary test equipment, schematic diagram and instructions. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson, (s)he will be able to:

32.4.59.1 IDENTIFY the purpose of blocking oscillators by selecting the correct statement from a choice of four. 100% accuracy is required.

32.4.59.2 IDENTIFY the Pulse Width (PW), Pulse Repetition Time (PRT), Pulse Repetition Frequency (PRF), and Pulse Repetition Rate (PRR) of the output pulse of a blocking ocsillator, given a waveform diagram, by selecting the correct value or statement from a choice of four. 100% accuracy is required.

32.4.59.3 IDENTIFY the functions of components and circuit operation of a free-running blocking oscillator circuit, given a schematic diagram, by selecting the correct statement from a choice of four. 100% accuracy is required.

32.4.59.4 IDENTIFY the circuit and output waveforms of a free-running block oscillator by selecting the correct waveform or statement from a choice of four. 100% accuracy is required.

32.4.59.5 IDENTIFY causes of and techniques used to eliminate overshoot or ringing in a blocking oscillator circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON 1

Blocking Oscillators

1. Which of the oscillators listed below would produce a waveform other than a sine wave?

   a. Phase Shift
   b. Wienbridge
   c. LC
   d. Blocking

2. A certain blocking oscillator has a pulse repetition frequency of 625 pps. What is the PRT?

   a. 1.6 msec
   b. 16 msec
   c. 160 msec
   d. 1600 msec

3. Which of the terms listed below is the equivalent of pulse repetition frequency (PRF)?

   a. PW
   b. PRT
   c. PRR
   d. PRS

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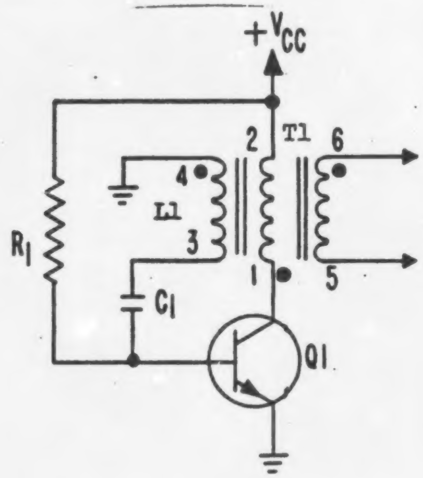
REFER TO FIGURE 1 TO ANSWER QUESTIONS 4, 5, AND 6.



4. During the time a pulse is being generated

   a. C1 is discharging.
   b. C1 is charging.
   c. Ic is decreasing.
   d. Eo is zero.

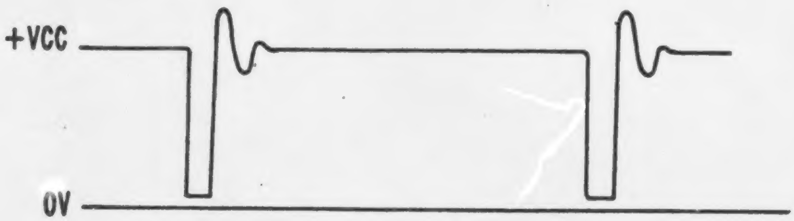
5. The pulse repetition frequency (PRF) of a blocking oscillator is determined primarily by the

   a. RC time of R1 and C1.
   b. primary winding of T1.
   c. RC time of R1, and L1.
   d. secondary winding of T1.

6. Regenerative feedback is accomplished by

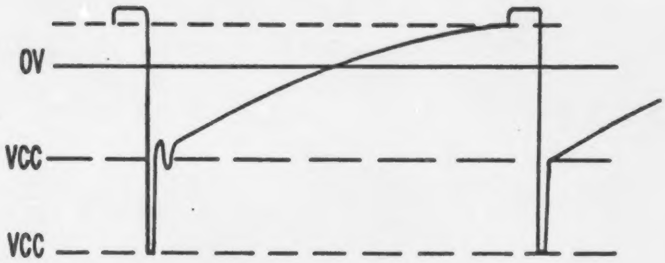
   a. R1 and C1.
   b. the tertiary winding.
   c. the collapsing field of the primary winding.
   d. inductive coupling primary to secondary.

7. Refer to the diagram shown. The waveform represents the



   a. output waveform.
   b. collapse of the primary winding.
   c. discharge of C1.
   d. collector waveform.

8. Refer to the figure shown. The waveform shown represents the waveform



   a. across the tertiary winding.
   b. at the collector of Q1.
   c. across the secondary winding.
   d. at the base of Q1.

9. Ringing in a blocking oscillator may be eliminated by using

   a. a swamping resistor across the tertiary winding.
   b. a diode across the primary winding.
   c. a diode across the tertiary winding.
   d. all of the above.

10. The primary cause of ringing in a blocking oscillator is the

   a. collapse of the primary magnetic field.
   b. expanding of the primary magnetic field.
   c. discharge of C1 through Q1.
   d. inductive coupling primary to secondary.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

JOB PROGRAM
FOR
LESSON 4

Blocking Oscillator

INTRODUCTION

This Job Program is designed to permit you to analyze the operation of the free running blocking oscillator. It will reinforce your knowledge of the free running blocking oscillator you studied in the narrative, programmed instruction or summary.

TERMINAL OBJECTIVE(S):

32.4.59 When the student completes this lesson, (s)he will be able to TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in blocking oscillator circuits when given a training device, prefaulted circuit board, necessary test equipment, schematic diagram and instructions. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson (s)he will be able to:

32.4.59.6 MEASURE and COMPARE waveforms and voltages in a blocking oscillator circuit, given a training device, circuit boards, test equipment and proper tools, schematic diagrams, and a job program containing reference data for comparison. Recorded data must be within limits stated in the job program.

SAFETY PRECAUTIONS:

Observe all standard safety precautions. Beware of all open and exposed connections; an energized circuit may have dangerous voltages present.

EQUIPMENT AND MATERIAL:

1. NIDA 203 Audio Oscillator
2. PC 203-6 Printed Circuit Board
3. Oscilloscope
4. AN/USM-207 Frequency Counter
5. 10X probe (1)
6. BNC Tee Connector (1)
7. BNC-BNC Cable (2)
8. Double Alligator Clip Shorting Wire (1)
9. Blocking Oscillator Schematic Diagram

PROCEDURE

1. Set up and energize the oscillscope for single trace operation using the channel #2 display mode with an EXTERNAL TRIGGER input. (Allow sufficient time for the oscilloscope to warm up).

2. Set up and energize the AN/USM-207 frequency counter to measure period. (Refer to job program Thirty Two-2, if necessary, in order to do this).

3. Connect the tee connector to the external trigger source jack of the oscilloscope. Connect one BNC cable between the NIDA 203 front panel jack and the tee connector. Connect the other BNC cable between the tee connector and the channel #1 input of the oscilloscope.

4. Remove the top cover from the NIDA 203 audio oscillator and install the PC-203 PCB.

5. Plug in and energize the NIDA 203 audio oscillator.

6. Turn the amplitude control on the front panel of the audio oscillator fully CW.

7. Connect the 10X probe to the channel #2 input to the oscilloscope.

8. Place the other end of the 10X probe between Pin #8 and ground of the NIDA 203 audio oscillator.

   a. Calculate the Pulse Repetition Rate (PRR) of the waveform shown on the scope____________.

   b. Calculate the width of the pulse (PW)_____________.

   c. Calculate the rest time from the scope presentation_______________.

9. On the AN/USM-207 frequency counter, set the channel "A" sensitivity control to the "FREQ C" position. Change the power switch from "STBY" to the "TRACK" position.

10. Set the time base switch (black knob) to 10^3 and the function switch to 10^2.

11. Disconnect the BNC-BNC cable running from the audio oscillator to the tee connector at the tee connector, and connect it to the channel "B" input of the AN/USM-207.

NOTE: Remember from a previous job program that the trigger volts controls are very sensitive and must be adjusted carefully to obtain a correct reading, and that channel "B" is used for period measurements and channel "C" for frequency measurements.

12. Set the channel "B" black knob at "10" and turn the red knob to midrange.

    a. What is the reading on the counter? ______________.

    b. Does this reading approximate the sum of your calculations in steps 8b plus 8c above (+ or - .2 msec)? _________________ yes/no.

13. Remove the BNC connector from channel "B" and connect it to channel "C" of the AN/USM-207.

14. Set the function switch to the FREQ position and the time base switch (black knob) to position 1.

15. Set the trigger volts control black knob at position 3 and turn the red knob fully CW.

    a. What frequency is being indicated by the counter? __________.

    b. Does this indication approximate the frequency you calculated from the scope in step 8(a) above? _____________ yes/no.

16. Disconnect the BNC connector from the channel "C" connection of the AN/USM-207 and connect it to the tee connector of the oscilloscope.

17. Turn off the AN/USM-207 frequency counter.

18. Set the oscilloscope for dual trace operation by pushing in the "ALT" switch of the display mode switches.

19. Connect the 10X probe to the base of Q1. The waveform at the base of Q1 is a result of the charging and discharging of C1. By observing the output and the waveform at the base of Q1 simultaneously, the relationship between the charging and discharing of C1 and the output can be seen.

NOTE: Notice the small sinusoidal pulse at the end of the main pulse. This pulse is known as "ringing" and is undesirable in practical blocking oscillators. The summary, narrative and programmed instruction discuss several methods of eliminating this "ringing", only one which will be shown here. Just to the left of the pulse transformer there is a small diode connected between the junction of C2 and R3 with the cathode connected to a pin which is not connected to any other components.

20. Deenergize the NIDA 203 audio oscillator.

21. Connect one alligator clip of a shorting wire to this pin and the other alligator clip to Pin #6. Notice that you have placed the diode directly across the primary winding of the pulse transformer.

22. Energize the NIDA 203 audio oscillator.

    a. What has happened to the "ringing" pulse? ____________. increased/decreased/remained the same.

    b. What has happened to the Pulse Repetition Frequency? ___________. increased/decreased/remained the same.

NOTE: Do not concern yourself with the change in frequency since a practical blocking oscillator will be designed to take this into consideration.

You have now completed the Job Program for blocking oscillators. You have analyzed the Pulse Repetition Frequency and the Pulse Repetition Time. You have also seen one method that is commonly used to eliminate ringing in an oscillator.

CHECK YOUR RESPONSES TO THIS JOB PROGRAM WITH THE ANSWER SHEET. IF YOUR RESPONSES AGREE WITH THE ANSWER SHEET, YOU MAY TAKE THE LESSON KNOWLEDGE TEST. IF YOUR RESPONSES DO NOT AGREE OR IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THIS JOB PROGRAM, REVIEW THE PROCEDURES OF THIS PROGRAM, ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS, OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOUR RESPONSES DO AGREE.

FAULT ANALYSIS

(PAPER TROUBLESHOOTING)

FOR

MODULE 32, LESSON 4

NOW THAT YOU HAVE COMPLETED THE KNOWLEDGE SECTION OF THIS LESSON, YOU ARE READY FOR PAPER TROUBLESHOOTING.

THE COMPUTER WILL ASSIGN YOU A SET OF PAPER TROUBLESHOOTING PROBLEMS ON BLOCKING OSCILLATORS. THESE PROBLEMS WILL HELP YOU DEVELOP THE MENTAL SKILLS REQUIRED IN ACTUAL TROUBLESHOOTING. YOU WILL BE GIVEN SYMPTOMS OF A FAILURE AND CIRCUIT MEASUREMENTS THAT WILL ALLOW YOU TO IDENTIFY THE PROBLEM.

AFTER YOU COMPLETE THE PAPER TROUBLESHOOTING SECTION, THE COMPUTER WILL ASSIGN YOU A PRACTICE TROUBLESHOOTING PROBLEM ON A FAULTY PRINTED CIRCUIT BOARD.

REMEMBER THAT REFERENCE VOLTAGES, WAVEFORMS, AND A SCHEMATIC ARE CONTAINED IN THIS STUDENT GUIDE FOR YOUR USE IN BOTH PAPER AND ACTUAL TROUBLESHOOTING PROBLEMS.

TERMINAL OBJECTIVE:

32.4.59 When the student completes this lesson, (s)he will be able to TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in blocking oscillator circuits when given a training device, prefaulted circuit board, necessary test equipment, schematic diagram and instructions. 100% accuracy is required.

ENABLING OBJECTIVE(S):

When the student completes this lesson, (s)he will be able to:

32.4.59.7 IDENTIFY the faulty component or circuit malfunction in a given blocking oscillator circuit, given a schematic diagram and failure symptoms, by selecting the correct fault from a choice of four. 100% accuracy is required.*

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*This objective is considered met upon successful completion of the terminal objective.

INFORMATION SHEETS
FOR
TROUBLESHOOTING PERFORMANCE TEST

INTRODUCTION:

Using the following six step troubleshooting procedure will aid you in determining which component is faulty. In the split method of troubleshooting, the base of Q1 has been selected as the starting point for this performance test. Based on your interpretation of the scope presentation at this point, you can determine which direction you should go.

EQUIPMENTS:

1. NIDA 203 Audio Oscillator
2. PC203-6 Printed Circuit Board
3. Oscilloscope
4. Simpson 260 Multimeter
5. 10X probe (1)
6. BNC Tee Connector (1)
7. BNC-BNC Cable (2)
8. Blocking Oscillator Schematic Diagram

INSTRUCTIONS:

1. Each student is required to determine the defective component in a prefaulted Blocking Oscillator circuit. Your six step troubleshooting sheet must indicate that you used accurate test measurements and a logical procedure to find the faulty component.

2. Standard test equipment will be available to you in the form of an oscilloscope, and a Simpson 260 multimeter. You will be expected to observe all safety precautions throughout the test. A safety violation will result in an automatic failure of the performance test. In that event you will be counselled and given remedial training.

3. You will take a numbered position in the test room. After a briefing by the Learning Center Instructor you will fill out the heading of the troubleshooting form. On a signal from the Learning Center Instructor you will then start the test. If at any time during the test you should require assistance, raise your hand. DO NOT LEAVE YOUR POSITION. A Learning Center Instructor will assist you with your trouble. If the trouble is due to no fault of your own, you will not be penalized and a time extension will be given if necessary. You will set up the equipment according to the specifications given in the troubleshooting performance test information sheet in this booklet.

TROUBLESHOOTING PERFORMANCE TEST

4. You must identify the faulty component to pass this performance test.

5. If you do not understand these instructions raise your hand and ask your Learning Center Instructor. If you do understand these instructions and upon a signal from your Learning Center Instructor you may now begin the Performance Test on the next page.

VOLTAGE/RESISTANCE CHART FOR BLOCKING OSCILLATORS

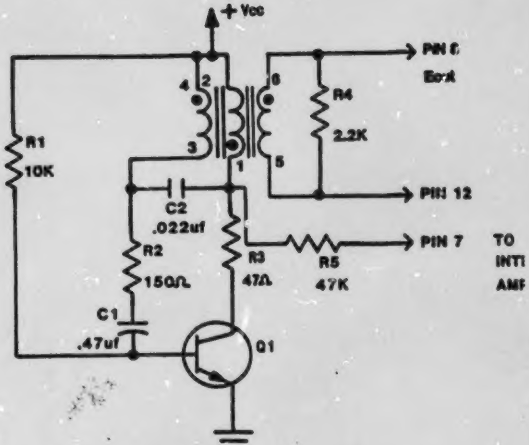
The following voltages and resistances were taken from a properly operating Blocking Oscillator with a Simpson 260 multimeter. All voltages and resistances were taken with reference to ground or circuit common. All voltages and resistances will be accurate to within ± 20% tolerance.

Point of Check	Voltage	Resistance
V_{cc}	20.8 VDC	1.7 K ohms
V_B Q1	-1.5 VDC	910 ohms
V_C Q1	17.8 VDC	1.65 K ohms
Pin #1 of T1	19.3 VDC	1.68 K ohms
Pin #3 of T1	20.6 VDC	1.72 K ohms

SCHEMATIC DIAGRAM

BLOCKING OSCILLATOR

PCB 203-6


+ Vcc
PIN 6
Eout
4
2
6
R4
2.2K
R1
10K
3
1
5
PIN 12
C2
.022uf
PIN 7
TO
INT
AM
R2
150Ω
R3
47Ω
R5
47K
C1
.47uf
Q1

BLOCKING OSCILLATOR

P.P. 87-

SUMMARY
LESSON 5

Crystal Controlled Oscillators

In any oscillator circuit, there is a method to select the desired operating output frequency. Crystal controlled oscillators provide extremely stable output frequencies. The property which allows a crystal to oscillate is known as the "piezoelectric effect" and is shown in Figure 1.

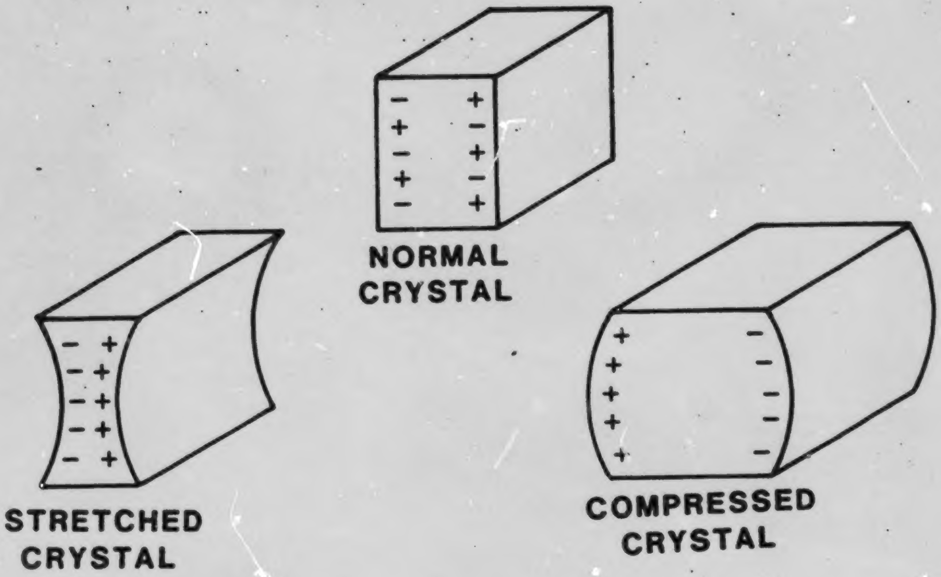
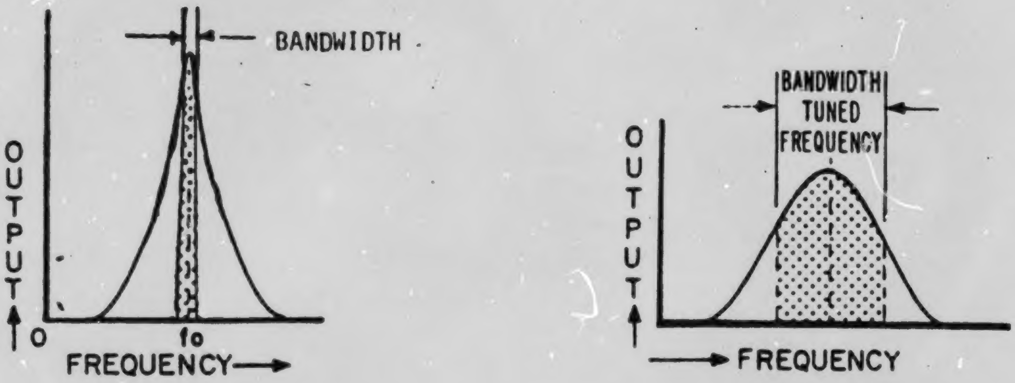


Figure 1

PIEZOELECTRIC EFFECT

As shown in the figure, tourmaline, Rochelle salt and quartz crystals will vibrate at their natural resonant frequencies when a voltage is applied. Conversely, vibrating crystals produce a voltage at a frequency which depends on the thickness of the crystal. The thinner a crystal is cut, the higher is both its natural resonant frequency and the AC voltage frequency it produces.

As in any oscillator, the AC voltage produced by a crystal oscillator will damp out unless regenerative (in-phase) feedback is received by the crystal. The crystal itself acts like an LC tank circuit at the desired frequency with a very narrow bandwidth and very high Q. Figure 2 compares the bandwidths of a crystal and an LC tank.



XTAL

LC

Figure 2

CRYSTAL VS LC TANK BANDWIDTH

Quartz is the most common material used in crystals. The schematic diagram for a crystal is shown in Figure 3.

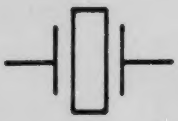


Figure 3

CRYSTAL SYMBOL

Electrically, a piece of unmounted quartz crystal is equivalent at a certain frequency to the series resonant circuit shown in Figure 4.

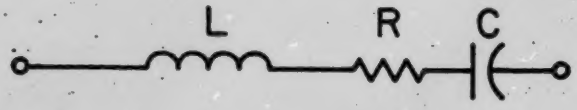


Figure 4

AC ELECTRICAL EQUIVALENT OF QUARTZ

When a crystal is mounted in a metallic holder, the electrodes attached to the crystal appear in parallel with the crystal as shown in Figure 5.

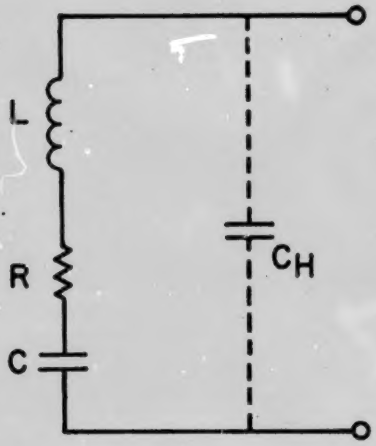


Figure 5

CRYSTAL EQUIVALENT CIRCUIT

A crystal oscillator operates at two distinct frequency points, or "modes". The series resonant mode is the natural resonant frequency of the crystal. The parallel mode (or anti-resonant mode) is caused by the parallel holder capacitance. The parallel mode occurs at a frequency slightly higher than that of the series resonant mode.

The effect of the two modes of operation are shown in the frequency response diagram in Figure 6.

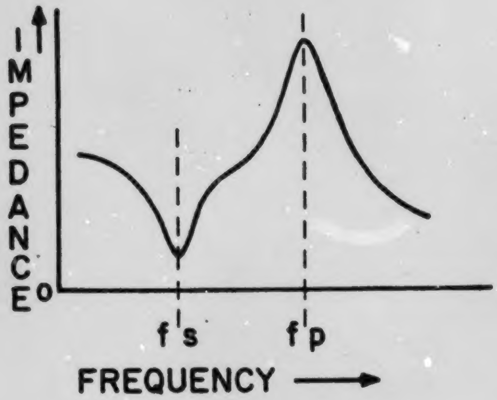


Figure 6

CRYSTAL IMPEDANCE VS FREQUENCY

As the frequency of a voltage applied to a crystal approaches the series resonant frequency (fs), the impedance of the crystal drops to a very low value. As the frequency of the applied voltage approaches the parallel resonant frequency (fp), the impedance increases sharply, thus exhibiting the characteristics of a parallel resonant tank.

The Pierce crystal oscillator shown in Figure 7 is an example of an oscillator circuit which operates in the anti-resonant mode.

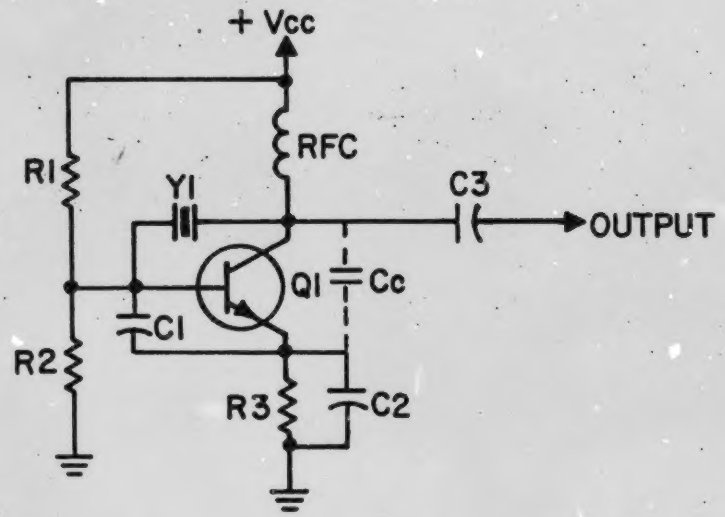


Figure 7

PIERCE XTAL OSCILLATOR

This oscillator is of the common Colpitts type, with the crystal in parallel with the voltage divider C1 and C_c. The impedance matching functions performed by the low reactance of C1 and the high reactance of C_c maintain the crystal's high Q and stable operating frequency. The ratio of the capacitive reactances of C1 and C_c determines the amount of regenerative feedback reaching the crystal.

The tickler coil (Armstrong) crystal oscillator shown in Figure 8 is an example of an oscillator circuit which operates in the series resonant mode.

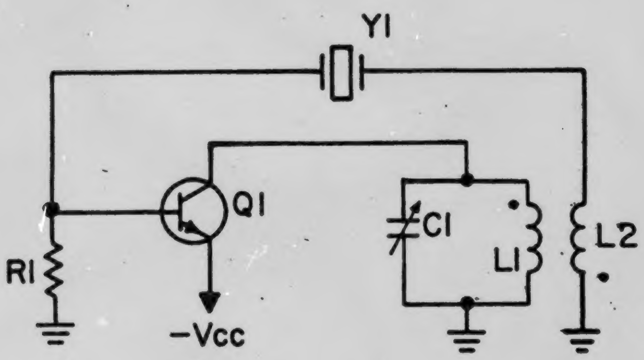


Figure 8

TICKLER COIL CRYSTAL OSCILLATOR

The L1C1 tank acts as the collector load, and is tuned to the crystal's resonant frequency. The crystal operates as a series resonant circuit to a single frequency which it passes to the base of Q1. The crystal filters out all other frequencies thus providing frequency stability.

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In crystal oscillators, exact adjustments may need to be made to the crystal due to circuit requirements or crystal aging. Small adjustments to its operating frequency, called "pulling the crystal", can be made by placing a variable capacitor or inductor in series or in parallel with the crystal. A small value trimmer capacitor is often used as shown by component C_4 in Figure 9.

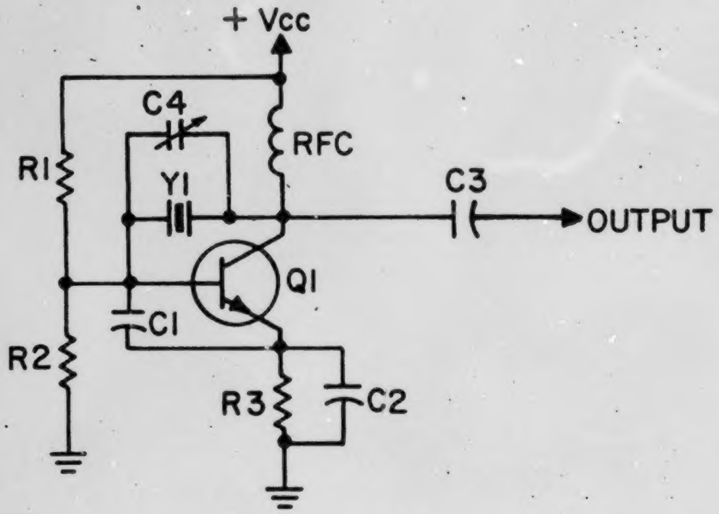


Figure 9

PIERCE CRYSTAL OSCILLATOR WITH TRIMMER

AT THIS POINT YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 5

Crystal Controlled Oscillators

TERMAINAL OBJECTIVE(S):

32.5.60 When the student completes this lesson, (s)he will be able to IDENTIFY the properties and characteristics of crystals, the component functions and modes of operation of Pierce and tickler coil crystal oscillator circuits, and techniques for adjusting the operating frequency of crystals by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson, (s)he will be able to:

32.5.60.1 IDENTIFY the properties of crystals, including piezoelectric effect, and the functions crystals perform in an oscillator circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

32.5.60.2 IDENTIFY the schematic symbol, AC equivalent circuit diagram, and electrical characteristics of a quartz crystal, both in isolation and when placed in a metal holder, by selecting the correct symbol, diagram, or statement from a choice of four. 100% accuracy is required.

32.5.60.3 IDENTIFY the two modes of crystal oscillator circuit operation by selecting the correct statement from a choice of four. 100% accuracy is required.

32.5.60.4 IDENTIFY the circuit diagram, component functions, and mode of operation of a Pierce crystal oscillator circuit, given the schematic diagram, by selecting the correct statement from a choice of four. 100% accuracy is required.

32.5.60.5 IDENTIFY the circuit diagram, component functions, and mode of operation of a tickler coil crystal oscillator circuit, given the schematic diagram, by selecting the correct statement from a choice of four. 100% accuracy is required.

32.5.60.6 IDENTIFY techniques used to make small adjustments to the operating frequency of a crystal by selecting the correct statement from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON 5

Crystal Controlled Oscillators

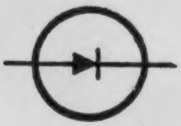
1. A crystal operates because of the piezoelectric effect, which means the crystal

   a. produces high gain amplification of a narrow band of input signals.
   b. produces an undamped AC output voltage when provided a DC input voltage.
   c. converts voltage to pressure distortions, and pressure to voltage.
   d. converts AC input signals to rectified DC, and DC input signals to rectified AC.

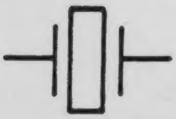
2. The frequency of a crystal oscillator is controlled by

   a. an LC tank.
   b. the crystal.
   c. an RC network.
   d. the RFC choke.

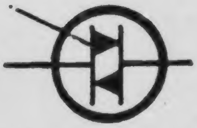
3. The schematic symbol for a crystal is



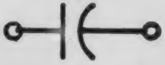
1.



2.



3.



4.

   a. 1
   b. 2
   c. 3
   d. 4

4. A crystal mounted in a holder has the property of

   a. a parallel resonant circuit.
   b. a series resonant circuit.
   c. either 1 or 2.

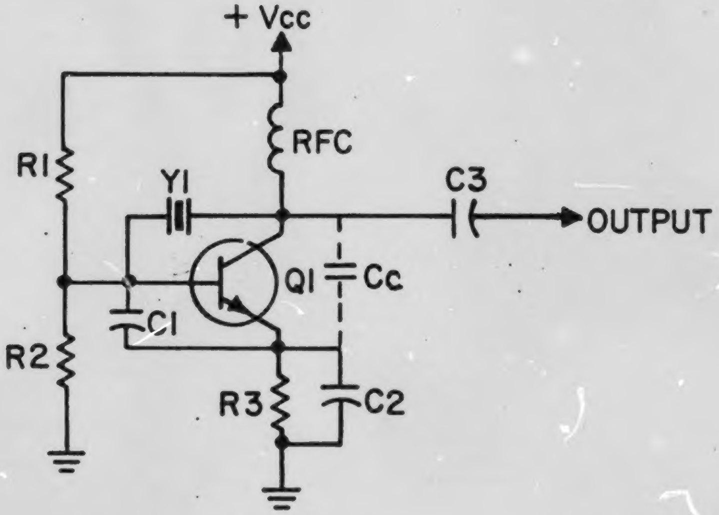
5. In a crystal oscillator, the parallel mode of operation occurs at a ________ which is slightly higher than that of the series resonant mode of operation.

   a. frequency
   b. temperature
   c. stability
   d. Q

6. A crystal operating in the series resonant mode has a characteristic (low/high) impedance, and a crystal operating in the parallel mode has a characteristic (low/high) impedance.

   a. low, high
   b. high, high
   c. low, low
   d. high, low

USE THE FIGURE BELOW OF A CRYSTAL CONTROLLED OSCILLATOR CIRCUIT TO ANSWER QUESTIONS 7 THROUGH 10.



7. The oscillator in the figure is called a ________ crystal oscillator, and operates in the ________________ mode.

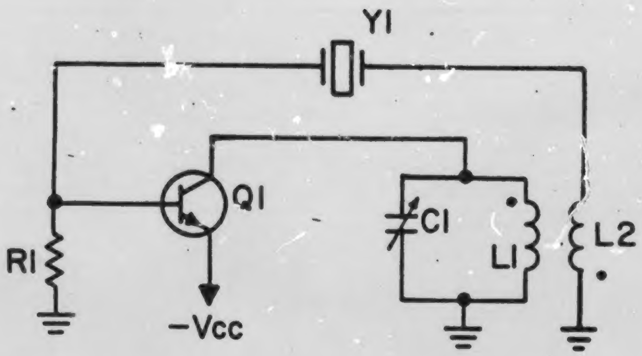
8. The optimum feedback voltage is provided by component __________.

9. A capacitive voltage divider is formed by C1 and ________.

10. When compared to a collector load resistor, the RFC in the circuit has (lower/higher) DC resistance with (lower/higher) AC reactance.

   a. higher, lower
   b. lower, higher
   c. lower, lower
   d. higher, higher

USE THE FIGURE BELOW OF A CRYSTAL CONTROLLED OSCILLATOR CIRCUIT TO ANSWER QUESTION 11.



11. The oscillator in the figure is called a _________ _________ oscillator, and operates in the _________ _________ mode of the crystal.

12. "Pulling the crystal" is performed in order to

   a. eliminate stray reactance.
   b. match oscillator input and output impedance.
   c. make the regenerative feedback in-phase.
   d. make small operating frequency adjustments.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

MODULE

THIRTY THREE

SPECIAL DEVICES

STUDENT'S GUIDE

JULY 1980

SUMMARY
LESSON 1

Delay Lines

Many electronic equipments use delay lines to trigger some circuits at later times than others. Most delay lines are divided into two categories: electromechanical and electromagnetic.

Electromechanical delay lines convert electrical input signals into mechanical motion (ultrasonic energy), transfer this energy as motion through some physical medium, and reconvert it to electrical output signals. The time delay depends on the medium used (such as mercury, a steel spring, quartz crystal) and the length of the delay line.

Figure 1 shows the signal characteristics for electromechanical delay lines.

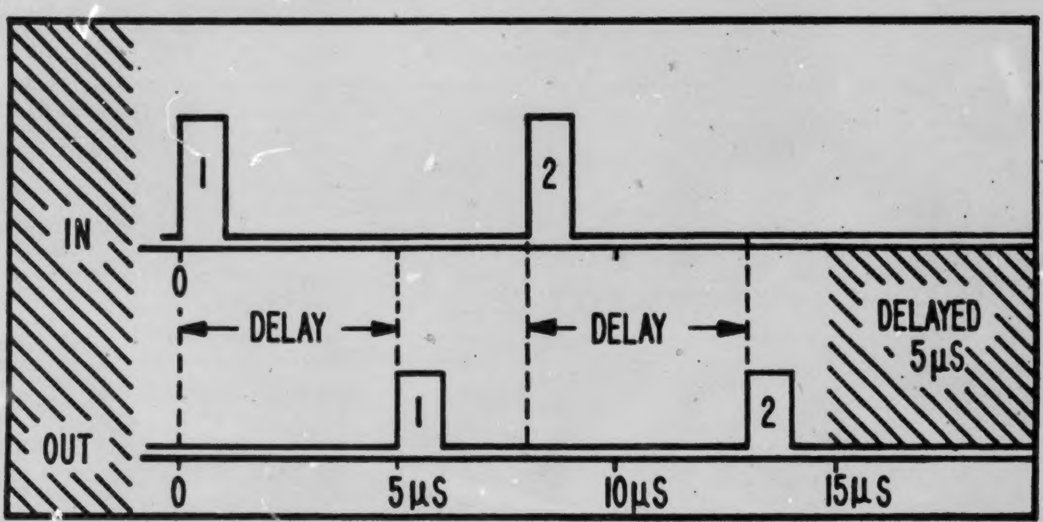


Figure 1

ILLUSTRATION OF ELECTROMECHANICAL TIME DELAY

The output signal is a delayed, non-distorted, and attenuated copy of the input signal.

One type of electromechanical delay line is made up of a column of mercury with a slab of quartz crystal at each end as shown in Figure 2.

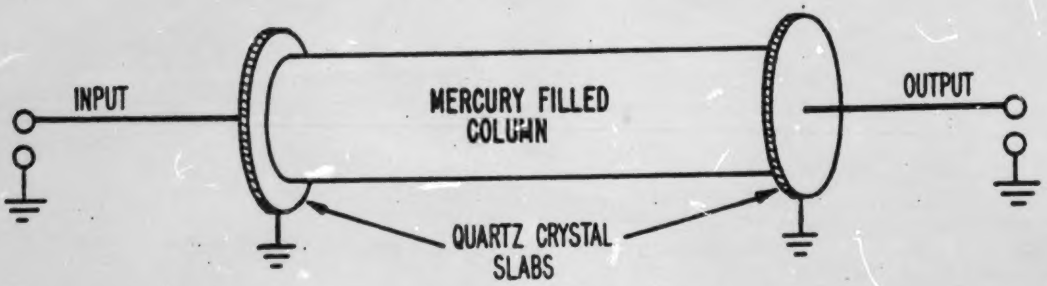

INPUT
MERCURY FILLED COLUMN
OUTPUT
QUARTZ CRYSTAL SLABS

Figure 2

ELECTROMECHANICAL MERCURY DELAY LINE

The mercury delay line uses the piezoelectric effect of the quartz crystals to convert electrical energy into mechanical energy, and reconvert mechanical energy back into electrical energy.

Electromagnetic delay lines are devices which function through the action of charging and discharging capacitance, and expanding and collapsing inductive, or magnetic, fields. Standard coaxial cable (coax), as shown in Figure 3, may be used as a electromagnetic delay line.

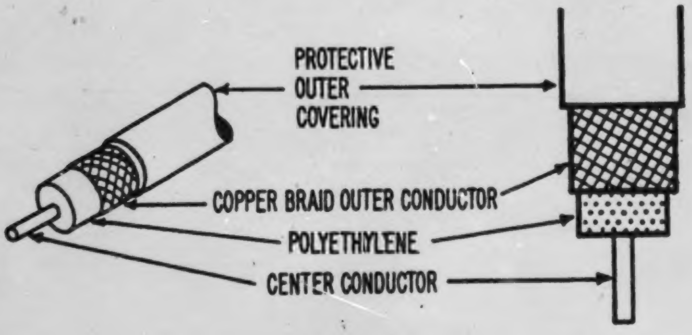

PROTECTIVE OUTER COVERING
COPPER BRAID OUTER CONDUCTOR
POLYETHYLENE
CENTER CONDUCTOR

Figure 3

STANDARD COAXIAL CABLE

The time delay in coaxial cable is directly proportional to cable length.

Spiral-wound coaxial cable, as shown in Figure 4, produces a time delay which is about 14 times greater than that of standard coax, because of the coiled center conductor.

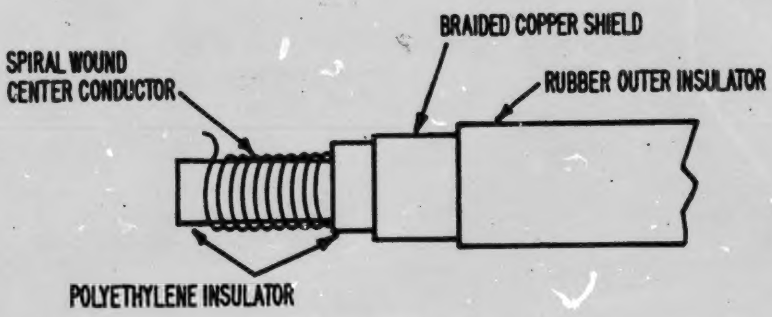

BRAIDED COPPER SHIELD
SPIRAL WOUND CENTER CONDUCTOR
RUBBER OUTER INSULATOR
POLYETHYLENE INSULATOR

Figure 4

SPIRAL COAX DELAY LINE

Spiral-wound coax is more commonly used because of its space-saving feature.

The lumped constant delay line, as shown in Figure 5, is used to produce very long delays when component size must be minimized. This type of line uses real capacitors and inductors to produce the delay.

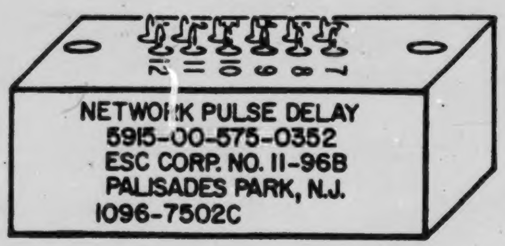

12
11
10
9
8
7
NETWORK PULSE DELAY
5915-00-575-0352
ESC CORP. NO. 11-96B
PALISADES PARK, N.J.
1096-7502C

Figure 5

LUMPED CONSTANT DELAY LINE

This type of delay line can be manufactured to provide exact time delays of relatively long duration in a very small package size.

Waveguides must be used as a delay line when the frequency of the input signal reaches the microwave frequency range. A waveguide is a cylindrical or rectangular metal pipe, as shown in Figure 6, commonly used as a microwave frequency transmission line.

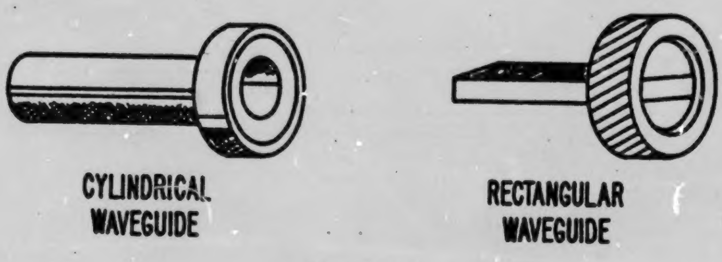


Figure 6

WAVEGUIDES

In electromagnetic delay lines as in electromechanical delay lines, the output signal has the same shape and pulse width as the input signal. Also, the output signal is attenuated. The amount of time delay and signal attenuation is directly proportional to delay line length.

As a rule of thumb, maximum energy transfer and minimum distortion occur in electromagnetic delay lines if the input source and output load impedances are matched to the delay line. An example of impedance matching is shown in Figure 7. Notice that $Z_g = Z_{in}$ and $Z_{out} = Z_L$

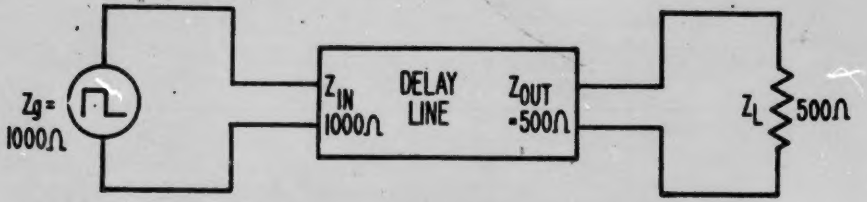


Figure 7

DELAY LINE IMPEDANCE MATCHING

AT THIS POINT YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PART OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 1

Delay Lines

TERMINAL OBJECTIVE(S):

33.1.61 When the student completes this lesson (s)he will be able to IDENTIFY the purpose, function and operational characteristics of electromechanical and electromagnetic delay lines by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson (s)he will be able to:

33.1.61.1 IDENTIFY the purpose of delay lines by selecting the correct statement from a choice of four. 100% accuracy is required.

33.1.61.2 IDENTIFY the general principle by which time delay is accomplished in an electromechanical delay line by selecting the correct statement from a choice of four. 100% accuracy is required.

33.1.61.3 IDENTIFY the operating methods and characteristics of specific electromechanical delay line devices by selecting the correct statement from a choice of four. 100% accuracy is required.

33.1.61.4 IDENTIFY the general principle by which time delay is accomplished in an electromagnetic delay line by selecting the correct statement from a choice of four. 100% accuracy is required.

33.1.61.5 IDENTIFY the operating methods and characteristics of specific electromagnetic delay line devices by selecting the correct statement from a choce of four. 100% accuracy is required.

33.1.61.6 IDENTIFY the relationship between impedance matching and the operating characteristics of a delay line by selecting the correct statement from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON 1

Delay Lines

1. Delay lines are used in electronic circuits to slow down ________ signals.

2. The general type of delay line which uses the energy of mechanical motion is called __________.

3. A mercury delay line functions by using

   a. capacitance and inductance.
   b. reactance and resistance.
   c. mechanical motion.
   d. electromagnetic waves.

4. Electromagnetic delay lines use actual or apparent __________ and __________ to cause time delay.

   a. inductors, resistors
   b. capacitors, inductors
   c. capacitors, resistors
   d. resistors, diodes

5. Four meters of standard coaxial cable produce a .04 microsecond time delay. Therefore, __________ meters of the same cable would produce a .08 microsecond time delay.

   a. 2
   b. 6
   c. 8
   d. 16

6. In electromagnetic delay lines, the input and output signals have (the same/different) shapes.

7. Attenuation in delay lines means that the output signals have ____________ ____________ when compared to the input signals.

   a. lower frequencies
   b. different shapes
   c. higher frequencies
   d. smaller amplitudes

8. The _________ __________ delay line, per unit length, produces a longer time delay than the _________ __________ delay line.

   a. standard coax, lumped constant
   b. standard coax, spiral-wound coax
   c. spiral-wound coax, standard coax
   d. spiral-wound coax, lumped constant

9. Waveguides are used as delay lines at microwave frequencies to

   a. replace mercury delay lines.
   b. replace lumped constant and coax delay lines.
   c. match input and output pulse widths and waveforms.
   d. provide longer time delays using less space.

10. An input source to an electromagentic delay line has an impedance of 2000 ohms. The output load has an impedance of 1000 ohms. Maximum energy transfer will occur if the delay line input impedance is __________ ohms, and output impedance is _________ ohms.

   a. 2000, 1000
   b. 2000, 2000
   c. 1000, 1000
   d. 1000, 500

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS, (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

SUMMARY
LESSON 2

Dummy Loads

Many times you will find it necessary to test electronic equipments, such as power supplies and transmitters, without connecting them to their normal load devices. In these situations, dummy loads are used. A dummy load is a device that appears to any equipment under operation to be the normal load.

Figure 1 shows two common examples where electrical dummy loads can be used.

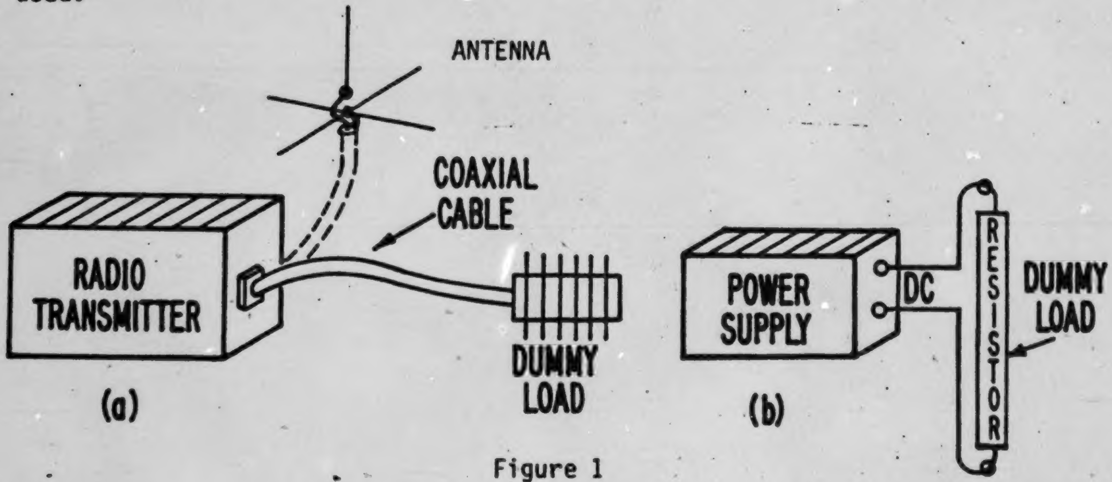


Figure 1

DUMMY LOAD APPLICATIONS

When using dummy loads, the normal loads are isolated electrically from the circuits. The dummy loads allow you to operate and troubleshoot the radio transmitter and power supply without the problems related to using the normal loads. Dummy loads can replace the normal loads of circuits as well as of complete equipments.

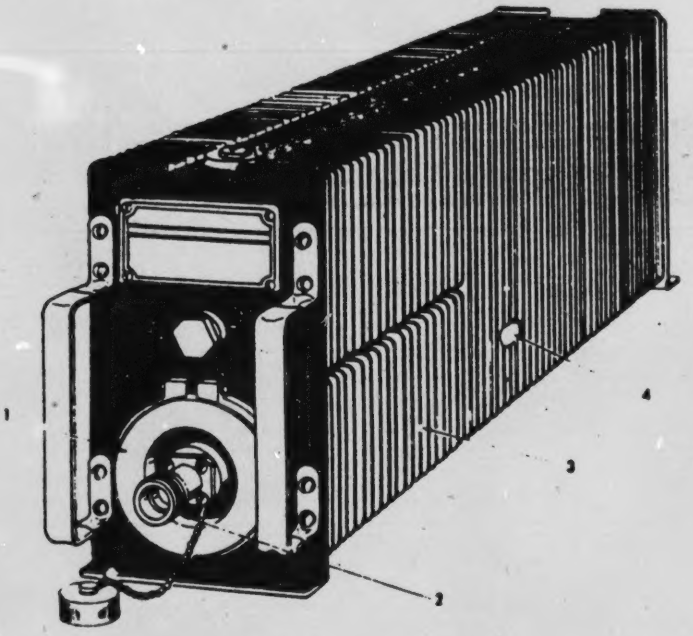
A resistive dummy load converts the output energy from an operating equipment into heat. Two requirements for using all resistive dummy loads are:

1. The dummy load resistance must be as close as possible to the actual value of load resistance (R_L).
2. The dummy load power rating must be high enough to dissipate the power produced by the equipment or circuit.

A resistive dummy load can be a fixed resistor or a rheostat. Fixed resistors of proper values and power ratings are commonly used as dummy loads for AC or DC power supplies over a wide range of power outputs.

A resistive dummy load which replaces the antenna of a radio transmitter must be capable of dissipating a large amount of heat caused by the RF energy. Two types of dummy load used for this purpose are coaxial and waveguide dummy loads. In both types, the resistive element is made of a special mixture containing powdered graphite with an adhesive compound. This mixture is formed into a tapered cone, and placed into a heat sink to dissipate the heat into the air.

Coaxial dummy loads are used at frequencies in the RF communications range. A coaxial cable transmission line connects the radio transmitter to the dummy load. In this case the fixed output impedance of the transmitter (usually 50 ohms resistive) is matched by a 50 ohm coax cable and 50 ohm dummy load. Figure 2 shows an exterior view of a coaxial dummy load.



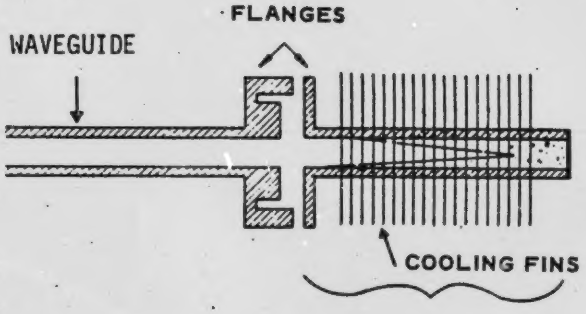
1. Resistive element
2. RF input connector
3. Metal cooling fins
4. Resistive element extending down through cooling fins

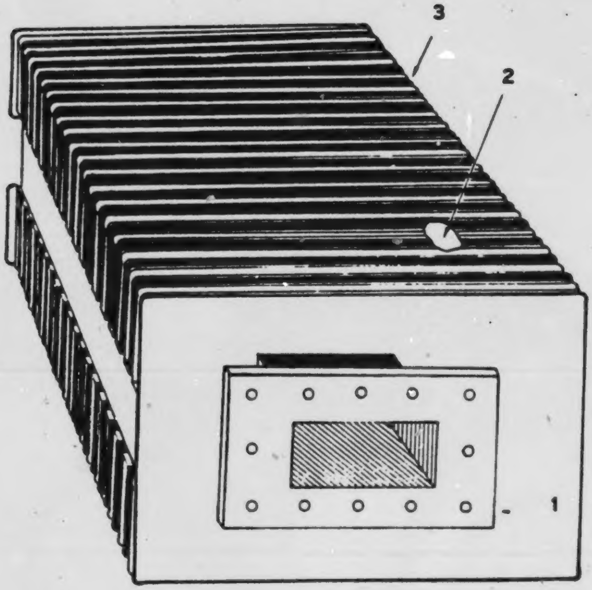
Figure 2

COAXIAL DUMMY LOAD (EXTERIOR VIEW)

Waveguide dummy loads normally are used at microwave (radar) frequencies. A waveguide transmission line connects the radio transmitter to the dummy load. The resistive element is contained within a piece of waveguide.

Figure 3 illustrates a waveguide dummy load.





1. Flange used to bolt waveguide dummy load to waveguide.

2. Waveguide extends through cooling fins.

3. Cooling fins.

Figure 3

WAVEGUIDE DUMMY LOAD

In both coaxial and waveguide dummy loads, some RF energy is not dissipated as heat and leaks into the surrounding space. When radio silence is required, the Commanding Officer must give permission to transmit even into a dummy load.

The previous discussion has dealt with electrical dummy loads. One other category of dummy load is the mechanical dummy load which is a device that simulates mechanical loads.

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PROGRESS CHECK
LESSON 2

Dummy Loads

TERMINAL OBJECTIVE(S):

33.2.62 When the student completes this lesson (s)he will be able to IDENTIFY the purpose, function, and operating characteristics of dummy loads by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson (s)he will be able to:

33.2.62.1 IDENTIFY the purpose of electrical dummy loads by selecting the correct statement from a choice of four. 100% accuracy is required.

33.2.62.2 IDENTIFY the operating characteristics and applications of resistive dummy loads by selecting the correct statement from a choice of four. 100% accuracy is required.

33.2.62.3 CALCULATE the resistance and power requirements of dummy loads used on power supplies, given the voltage and current of the actual load, by selecting the correct value from a choice of four. 100% accuracy is required.

33.2.62.4 IDENTIFY the operating characteristics and applications of coaxial and waveguide dummy loads by selecting the correct statement from a choice of four. 100% accuracy is required.

33.2.62.5 CALCULATE the power requirements of dummy loads used on transmitters, given transmitter outputs, by selecting the correct value from a choice of four. 100% accuracy is required.

33.2.62.6 IDENTIFY the purpose of, and examples of, mechanical dummy loads by selecting the correct statement from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON 2

Dummy Loads

1. A dummy load is used in the testing of an electronic equipment to

   a. reduce the output power of the equipment under test.
   b. replace the normal load on the equipment under test.
   c. reduce the output load resistance of the normal load.
   d. increase the impedance of the normal load.

2. A resistance dummy load converts its output energy into ________ energy

   a. heat
   b. light
   c. acoustical
   d. electrical

3. The component you would use as a dummy load on a power supply is a

   a. coil.
   b. capacitor.
   c. diode.
   d. resistor.

4. The output load of a power supply is 200 volts and 4 amperes. A dummy load on this power supply must have a resistance equal to __________ ohms.

5. A normal load for a power supply requires 300 volts and 3 amperes. A dummy load on the same power supply must have a minimum power rating of _______________ watts.

6. A coaxial dummy load normally would be used in place of a(n) (RF antenna/power supply load).

7. A waveguide dummy load is used at (radio communication/microwave) frequencies.

8. A radio transmitter output is 1000 watts at 50 ohms impedance. A dummy load on the same transmitter must have a power rating of at least ___________ watts.

9. Dummy loads on radio transmitters (will/will not) leak RF energy into space.

10. A lead weight used to test the lifting capability of a fork lift is an example of a(n) ____________ dummy load.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

SUMMARY
LESSON 3

Special Solid State Devices

The electronic revolution is producing a continuous series of new special devices. Many of these, although originally created to solve a specific problem, are finding seemingly endless applications. Among the more important new devices are those in the optoelectronic group (LEDs, photodiodes, etc.), the varactor diode, and the triac.

Optoelectronic devices either produce or use light in their operation. Their schematics typically show two arrows pointing either away from the basic symbol (if light is produced) or in toward it (if light is used). The first of these, the Light Emitting Diode (LED) is shown with its schematic in Figure 1.

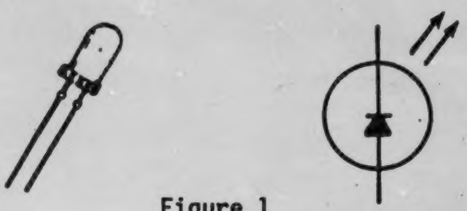


Figure 1

LED

The LED is a diode which, when forward biased, produces visible light. Their extremely small size, low operating voltage and long life make LEDs ideal replacements for incandescent bulbs used as panel indicators and in displays in pocket calculators and the like. Typically, they are used in seven-segment displays like that shown in Figure 2.

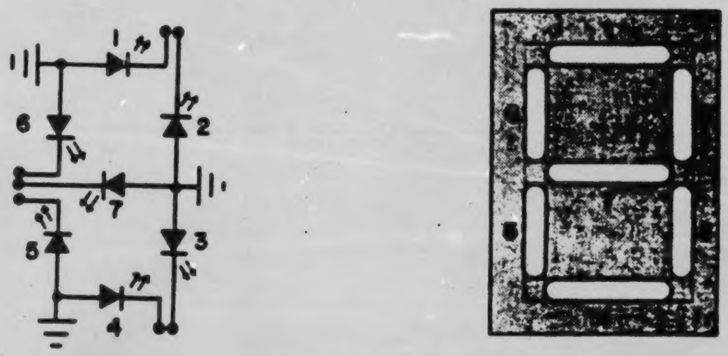


Figure 2

SEVEN SEGMENT LED DISPLAY

This display uses seven LED segments (or bars) which can be lit in different combinations to form any number from "0" through "9". Each segment draws about 10 mA of current when lit. Displays are of the common-anode type, as shown, or the common-cathode type. Often several displays are packaged together in a stack, as for 7- or 9-digit calculators.

A second optoelectronic device, one that uses rather than produces light, is the photodiode, shown with schematic in Figure 3.

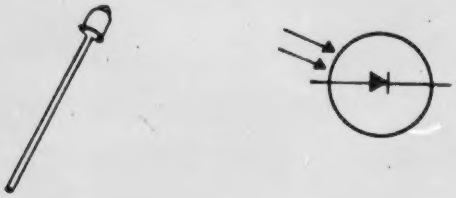


Figure 3

PHOTODIODE

The photodiode is a light-controlled variable resistor. A transparent "window" placed over the semi-conductor chip allows light to reach the diode. The photodiode is reverse biased and conducts current in direct proportion to the intensity of the light source. Photodiodes are used in computer card readers, photographic light meters, and some types of optical scanning equipment.

Another light-using optoelectronic device, the phototransistor, is even more sensitive to light and capable of higher output current than the photodiode. Four types of phototransistors are shown, with schematics, in Figure 4.

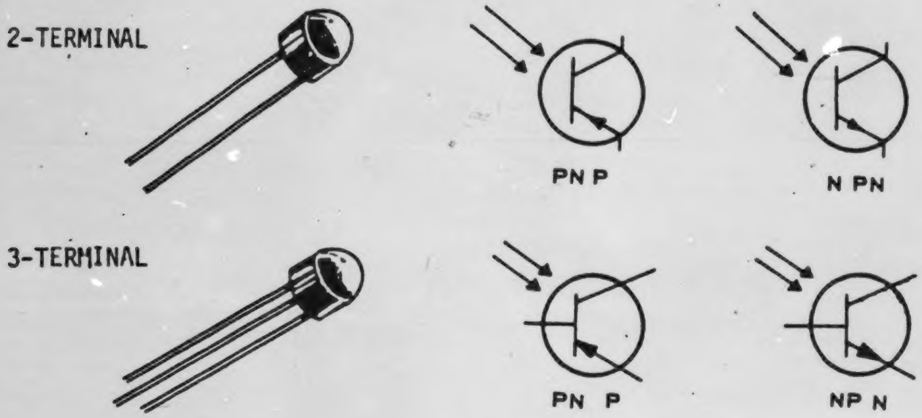


Figure 4

2-TERMINAL AND 3-TERMINAL PHOTOTRANSISTOR

The two-terminal NPN type, as an example, consists simply of a photodiode placed in the base-emitter circuit of a transistor. Light intensity determines the base current. In the three-terminal type, an additional lead is used to apply an electrical bias to the base which can alter the effect of light intensity on transistor conductivity (compensate for ambient light levels, etc.).

An older, similar device is the photoconductive cell, or photo cell, shown with its schematic in Figure 5.

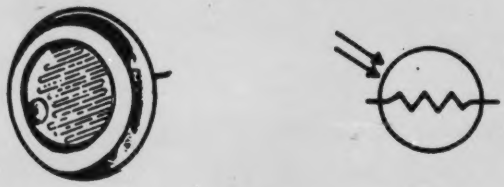


Figure 5

PHOTO CELL

The photo cell is a light-controlled variable resistor with a high light-to-dark ratio--typically 1:1000 or more. Photo cells are used in various timing and control circuits, such as automatic streetlight controllers.

Figure 6 shows the photovoltaic cell, or solar cell, with schematic.

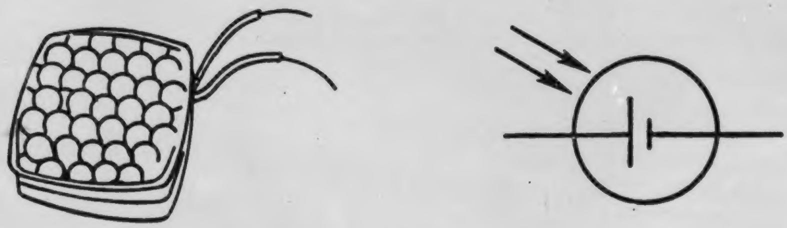


Figure 6

SOLAR CELL

When exposed to light, the solar cell produces about .45 volts and a current in proportion to its size. Connected in series or parallel like batteries, solar cells can produce higher voltages and currents. They are widely used in communications satellites and solar-powered homes.

The optical coupler, shown in Figure 7, combines two optoelectronic devices to achieve total electrical isolation of circuits.

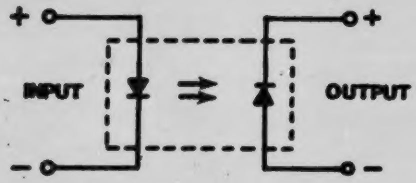


Figure 7

OPTICAL COUPLER

The coupler consists of a forward-biased LED and a reverse-biased photodiode encapsulated so that changes in the input signals are transmitted by light to the output. Couplers like this are suitable for frequencies in the low megahertz range. Where more output is required, couplers combining a phototransistor with an SCR can be used. Optical scanners are replacing transformers in low voltage and current applications, such as digital control circuits.

The varactor diode, the first of two non-optical devices to be covered, is shown with its schematic in Figure 8.

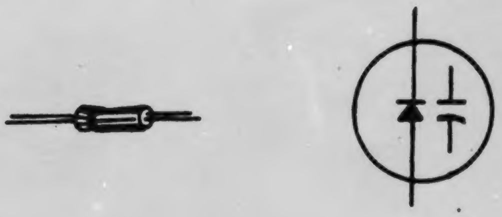


Figure 8

VARACTOR DIODE - PICTORIAL AND SCHEMATIC

128

The varactor, or varicap, is a diode made to function like a variable capacitor. This is possible due to the effect of reverse biasing on the size of the depletion region surrounding a diode's PN junction, which is illustrated in Figure 9.

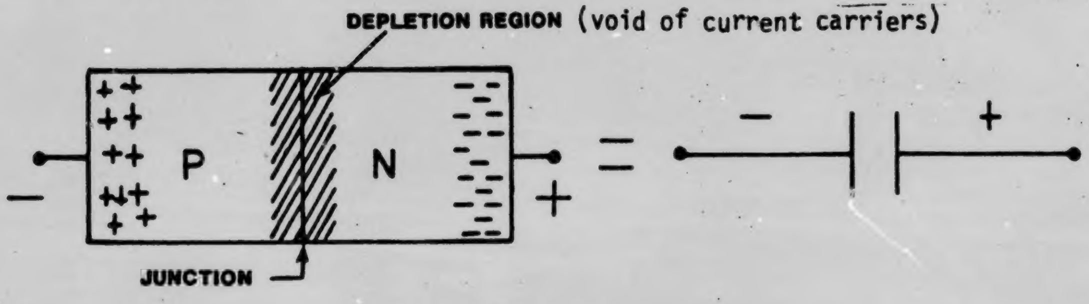

DEPLETION REGION (void of current carriers)
P
N
JUNCTION
−
+
=
−
+

Figure 9

PN JUNCTION VS. CAPACITANCE

Increasing the reverse bias voltage causes the depletion region to widen into an insulating gap comparable to the dielectric in a capacitor. Applying the formula $C = \frac{A\,K}{d}$ (where A = plate area, K = a constant value, and d = distance between plates), it is found that the varactor's capacitance (C) is inversely proportional to applied reverse bias.

Varactors have replaced variable capacitors in many circuit applications, especially sophisticated tuning circuits. One advantage of the varactor is that it allows a DC voltage to be used to tune a circuit with a potentiometer as shown in Figure 10.

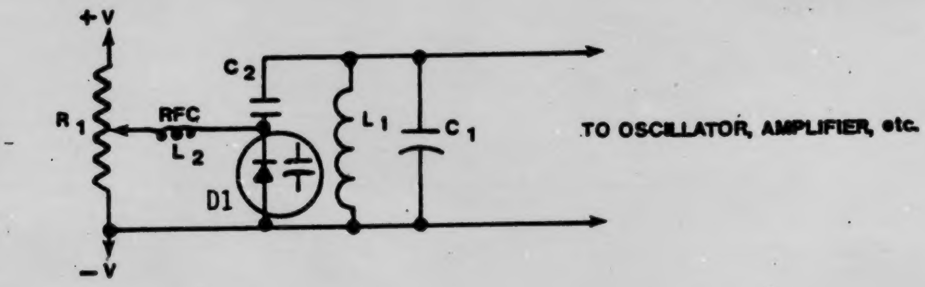

+V
C2
R1
RFC
L2
L1
C1
D1
TO OSCILLATOR, AMPLIFIER, etc.
−V

Figure 10

VARACTOR TUNED TANK

The variable DC voltage felt at R1 acts to reverse bias varactor diode D1. Because D1 is in series with C2 and the equivalent capacitance of C2 and D1 is in parallel with tank circuit L1-C1, any variation in the DC voltage at R1 will vary both the capacitance of D1 and the resonant frequency of the tank circuit.

The triac, the last special device to be covered, is a three-terminal device similar to an SCR, as Figure 11 shows.

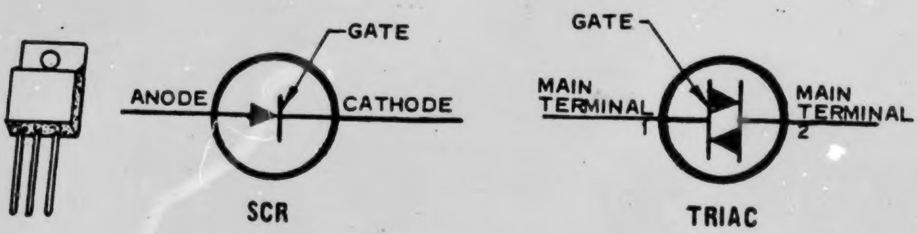

GATE
ANODE
CATHODE
SCR
GATE
MAIN TERMINAL 1
MAIN TERMINAL 2
TRIAC

Figure 11

TRIAC VS SCR SCHEMATIC SYMBOLS

The triac is essentially two SCRs back to back, sharing a common gate. It controls current flow during both alternations of an AC cycle, instead of only one as the SCR does, and conducts in both directions. The triac is widely used in circuits which control light intensity and motor speed. A comparison of the waveforms seen at the input, gate, and output of the SCR and the triac is shown in Figure 12.

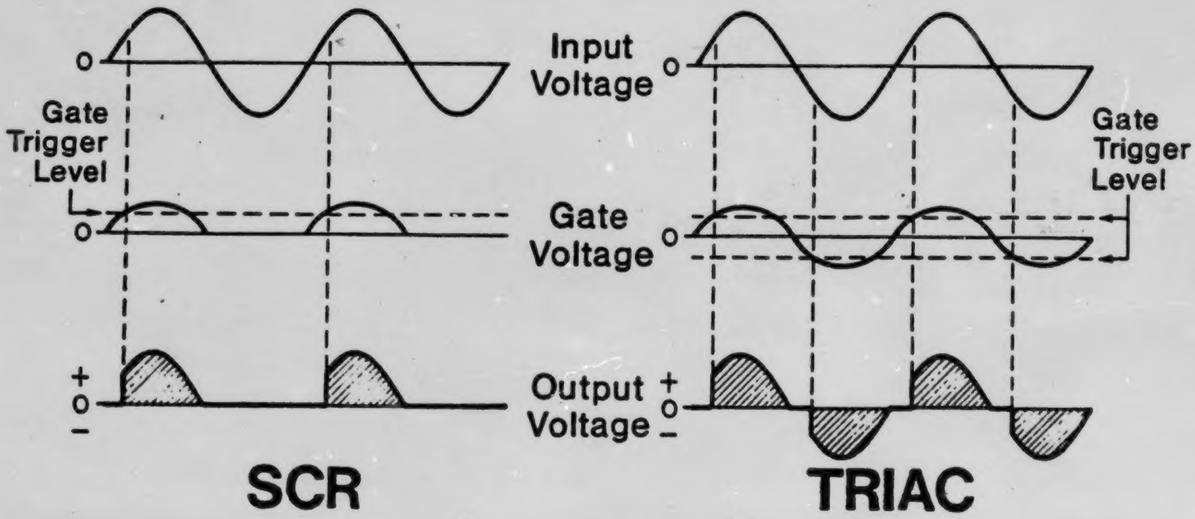

Input Voltage
Gate Trigger Level
Gate Voltage
Output Voltage
0
+
-
SCR
TRIAC

Figure 12

SCR VS TRIAC WAVEFORMS

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 3

Special Solid State Devices

TERMINAL OBJECTIVE(S):

33.3.63 When the student completes this lesson (s)he will be able to IDENTIFY schematic symbols, operating characteristics and applications for optoelectronic devices (LED, photodiode, phototransistor, photocell, solar cell, and optical coupler), the varactor diode, and the triac, by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson, (s)he will be able to:

33.3.63.1 IDENTIFY the schematic symbol, operating characteristics, and applications for the light emitting diode (LED) by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.3.63.2 IDENTIFY the schematic symbol, operating characteristics, and applications for the photodiode by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.3.63.3 IDENTIFY the schematic symbol, operating characteristics, and applications for two- and three-terminal phototransistors by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.3.63.4 IDENTIFY the schematic symbol, operating characteristics, and applications for the photocell by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.3.63.5 IDENTIFY the schematic symbol, operating characteristics, and applications for the photovoltaic cell by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.3.63.6 IDENTIFY the schematic symbol, operating characteristics, and applications for an optical coupler by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.3.63.7 IDENTIFY the schematic symbol, operating characteristics, and applications for the varactor diode by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.3.63.8 IDENTIFY the schematic symbol, operating characteristics, and applications for the triac by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON 3

Special Solid State Devices

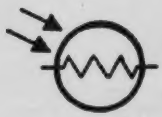
1. The LED, or light emitting diode, (uses/produces) light when it is (forward/reverse) biased.

2. The photodiode (produces light/conducts when exposed to light) and it is (forward/reverse) biased.

3. In a three-terminal phototransistor, conduction is controlled by

   a. light intensity and length of exposure to light.
   b. applied electrical bias and electrostatic fields.
   c. electrostatic fields and length of exposure to light.
   d. applied electrical bias and light intensity.

4. The schematic symbol below represents a



   a. photodiode.
   b. phototransistor.
   c. photocell.
   d. photovoltaic (solar) cell.

5. Which of the following devices is NOT a light-controlled variable resistor?

   a. Photodiode
   b. Phototransistor
   c. Photocell
   d. Photovoltaic (solar) cell.

6. The photocell is most similar in operation to a(n)

   a. photovoltaic cell.
   b. photodiode.
   c. LED.
   d. triac.

7. The photovoltaic cell produces (light/voltage/heat) when (voltate is applied to it/light shines on it).

8. The simplest type of optical coupler combines what two optoelectronic devices?

   a. An LED and a photodiode.
   b. A photodiode and a solar cell.
   c. An LED and a phototransistor.
   d. A phototransistor and a photodiode.

9. When the reverse bias on a varactor diode INCREASES, this causes the size of its depletion region to (increase/decrease) and its capacitance to (increase / decrease).

10. The triac controls current

   a. during the positive alternation of an AC cycle only.
   b. during the negative alternation of an AC cycle only.
   c. during both alternations of an AC cycle.
   d. in DC circuits only.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

SUMMARY
LESSON 4

Field Effect Transistors

Impedance matching problems, resulting from the bipolar transistor's low input impedance, have for years lead scientists to search for a solid state device that retains the high input impedance of the vacuum tube. The result is the field-effect transistor, or FET. Whereas the bipolar transistor uses bias current to control conductivity, the FET is voltage-controlled, much like a vacuum tube.

Figure 1 shows how one type of FET, the junction type, or JFET, is constructed.

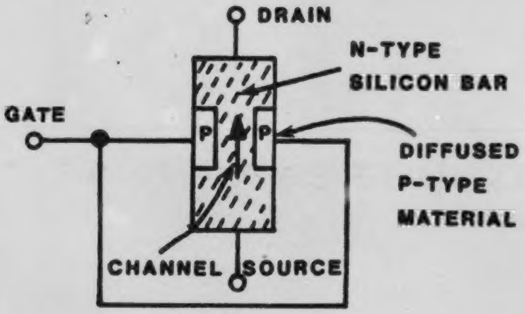


Figure 1

JFET

The three elements of the JFET operate like the familiar transistor and vacuum tube elements, "gate" like base and grid, and "source" and "drain" like emitter/collector and cathode/plate, respectively. The main body of this type of JFET is a bar of N-type material, connecting source and drain elements. Deposits of P-type material on either side are connected to form the gate element and create a narrow "channel" in the bar.

The key to FET operation is the effective cross-sectional area of the channel, which can be controlled by variations in the voltage applied to the gate. This is demonstrated in the figures that follow.

Figure 2 shows how the JFET operates in a zero gate bias condition.

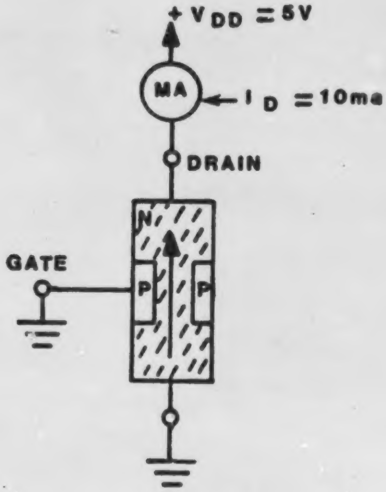

+ V DD = 5V
MA
I D = 10ma
DRAIN
N
GATE
P
P

Figure 2

JFET OPERATION-ZERO GATE BIAS

With the gate terminal tied to ground (0 volts), a drain supply (V_{DD}) of 5 volts gives a drain current (I_D) reading of 10 mA. In this condition, the bar represents a resistance of about 500 ohms.

In Figure 3, a small reverse bias is applied to the JFET's gate.

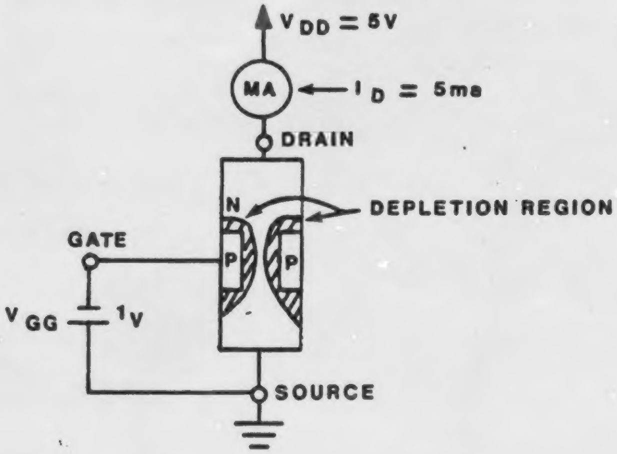

V DD = 5V
MA
I D = 5ma
DRAIN
N
DEPLETION REGION
GATE
P
P
V GG
1V
SOURCE

Figure 3

JFET OPERATION - REVERSE BIAS

One negative volt (V_{GG}) applied to the gate causes a reverse bias condition at the PN junction of the JFET. The resulting "depletion region" reduces the effective cross-sectional area of the channel, thus increasing source-to-drain resistance (to about 1 K Ohms) and decreasing current flow as shown.

The high gate input impedance of the JFET under reverse gate bias conditions can be seen by connecting a microammeter in series with V_{GG} as shown in Figure 4.

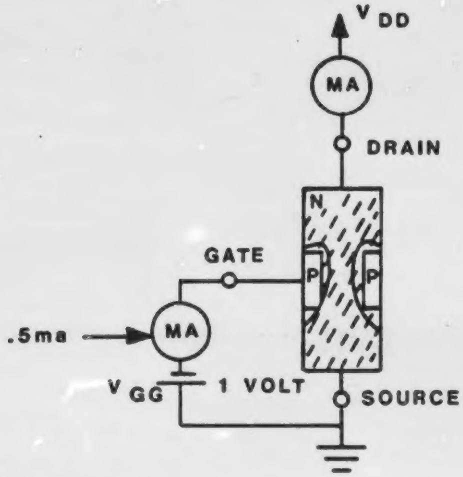
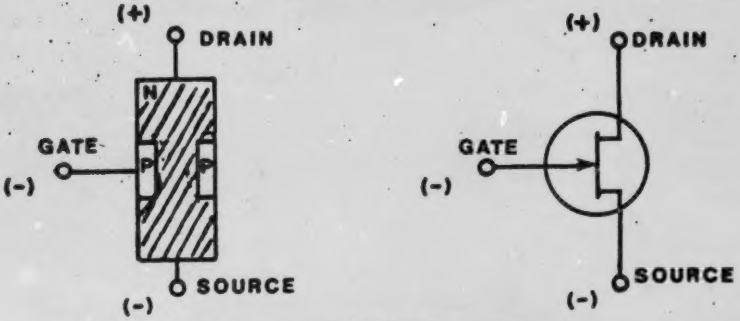


Figure 4

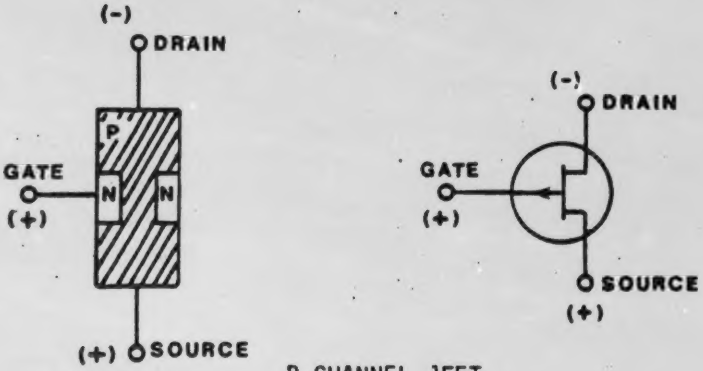
JFET INPUT IMPEDANCE

The very small amount of current flow (.5 microamps) results in a gate input impedance of about 2 megohms. By contrast, a bipolar transistor with a forward biased base-emitter junction, would have an input impedance of 1000 ohms or less.

JFETS can be either N-channel type, as shown in the above example, or P-channel type. Operation, bias voltages, and schematic symbols for the two types are compared in Figure 5. Note the bias voltage potentials are reversed for the two JFET types, just as for bipolar transistors.


(+)
DRAIN
N
GATE
(-)
P
P
SOURCE
(-)
(+)
DRAIN
GATE
(-)
SOURCE
(-)

N-CHANNEL JFET


(-)
DRAIN
P
GATE
(+)
N
N
(+)
SOURCE
(-)
DRAIN
GATE
(+)
SOURCE
(+)

P-CHANNEL JFET

Figure 5

SYMBOLS AND PICTORAL WITH BIAS VOLTAGE-JFETS

Figure 6 demonstrates the operation of an N-channel JFET in a basic common-source amplifier circuit.

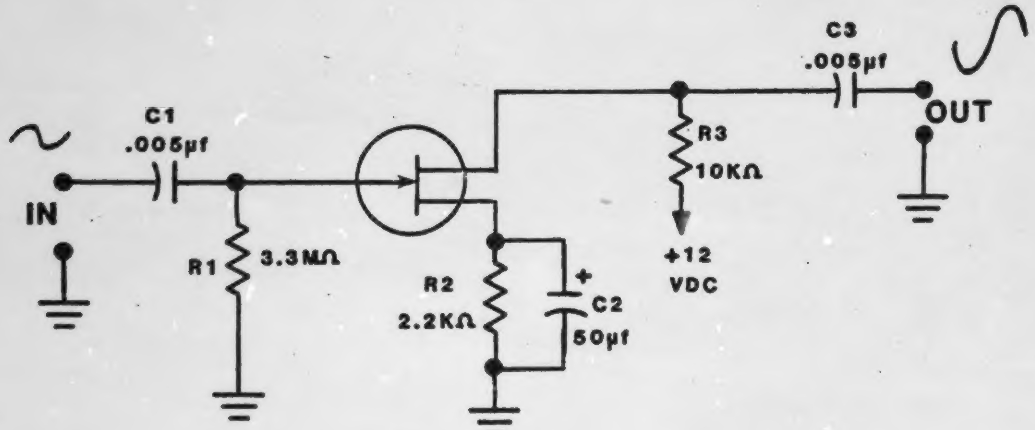


Figure 6

FET COMMON SOURCE AMPLIFIER

Circuit characteristics include high input impedance and a voltage gain of about 10 (20 db.). The function of components and the 180° phase shift are similar to those in common-cathode VT and common-emitter transistor circuits. The reason for the phase shift here is the effect of the input signal on the JFET's gate bias. On the positive alternation, reverse bias is decreased. This increases the channel's effective cross-section, decreases source-to-drain resistance, and increases current. The result is an increase in the voltage drop across R3 and a decrease in drain voltage. On the negative alternation, reverse gate bias is increased, and circuit action is reversed.

An FET with even higher input impedance than the JFET is the "metal oxide semiconductor field-effect transistor" or MOSFET. Its extremely high input impedance, 10 to 100 million megohms (10^{13}-10^{14} ohms), will not load down preceeding circuits and makes the MOSFET an extremely efficient input device.

Figure 7 shows how one type of MOSFET, the N-channel type, is made.

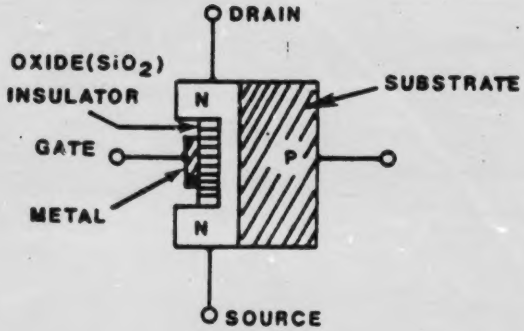


Figure 7

N CHANNEL MOSFET CONSTRUCTION

The MOSFET is a four-element device. Source and drain elements are connected by a "channel" of N-type material just as in an N-channel JFET. The channel material forms a PN junction with the "substrate" material. Although biasing the substrate element permits control of the MOSFET's gain characteristics, often the substrate terminal is connected directly to the source terminal, and the biasing capability is not used.

The gate element is made of metal and is electrically insulated from the source-drain channel by a layer of silicon oxide (SiO_2). This total insulation results in the MOSFET's extremely high input impedance and gives rise to another common name for the device: "insulated gate field effect transistor," or IGFET.

MOSFETs can be N-channel or P-channel, and single-gate or dual-gate. Schematic symbols for dual-gate MOSFETs (only) are show in Figure 8.

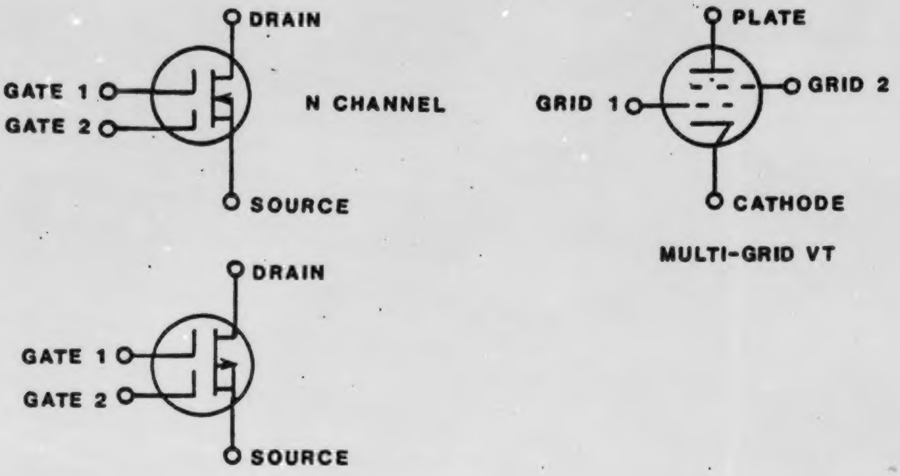

DRAIN
GATE 1
GATE 2
SOURCE
N CHANNEL
PLATE
GRID 1
GRID 2
CATHODE
MULTI-GRID VT
DRAIN
GATE 1
GATE 2
SOURCE

Figure 8

DUAL-GATE MOSFETS

As the figure shows, the gates are comparable to the grids in a multigrid VT. Either gate can control conduction independently, making the dual-gate MOSFET ideal for applications involving two separate signals (for example, AFC-controlled amplifiers).

To avoid accidental damage from static electricity, replacement MOSFETs come packaged with their leads shorted together with a shorting spring. This spring must not be removed until after the MOSFET is installed. A complete list of handling precautions for MOSFET devices is shown in Figure 9.

NOTICE

SPECIAL HANDLING OF MOS DEVICES

The MOS metal oxide semiconductor devices have a fairly high input resistance making them subject to damage from charges of static electricity through improper handling. The thin layer of oxide can be damaged from discharges of static electricity or improper handling in or out of circuit. The damage may be apparent immediately or may show up only after a short operating time. To avoid possible damage, the following procedures should be followed when handling or testing these devices.

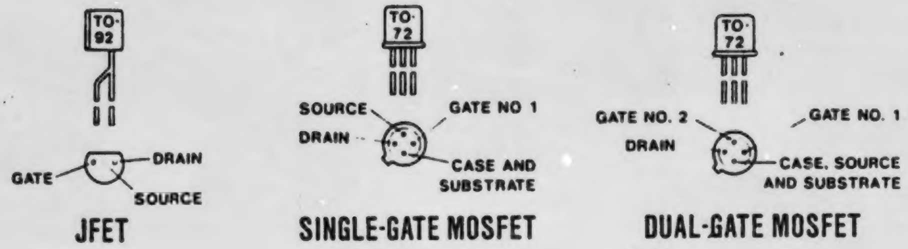
1. The use of synthetic clothing such as nylon should be avoided as this will generate static charges. Dry weather (relative humidity less than 30%) also tends to increase static buildup.
2. Keep the leads of the device in contact with a conducting material or shorted, except when testing, inserting or removing from the circuit.
3. A wrist strip with a 1 megohm resistor in series to common ground should be worn by the technician when inserting, removing or testing MOS devices.
4. Do not remove or insert an MOS device with the power to the circuit or test instrument "ON".
5. Do not apply or inject test signals into the circuit when an MOS device is used with the circuit power "OFF".
6. Do not turn the circuit power "ON" with an MOS device removed from the circuit. Charges can build up causing possible damage when the device is replaced in the circuit.
7. Soldering iron tips, metal bench tops, test equipment and tools should be grounded to a common ground along with the chassis of the set being serviced.
8. Soldering guns should not be used in MOS circuits. AC line leakage from the gun tip could cause damage to an MOS device.
9. Do not apply heat for longer than 10 seconds or closer than 1/16 of an inch to any MOS device when soldering. Use of a heat sink is recommended to prevent damage to the device.
10. Use the lowest wattage soldering iron possible when removing or inserting MOS devices on printed circuit boards.

Figure 9

MOSFET PRECAUTIONS

Some MOSFETs have protection diodes built in, back to back, designed to limit transient voltage without causing distortion. Even so, it is best to observe all the above precautions when working with any type of MOSFET equipment.

Some common FET base diagrams are shown in Figure 10.



JFET SINGLE-GATE MOSFET DUAL-GATE MOSFET

Figure 10

FET BASE DIAGRAMS

Pin arrangements for FETs are not standardized. For accurate identification of leads, a data book should be used. Signal tracing or signal injection methods can be used to locate faulty FET stages. Voltage measurements using a high impedance voltmeter are recommended. An ohmmeter should not be used, since ohmmeter battery voltages vary widely and may easily exceed maximums permitted between FET elements.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 4

Field Effect Transistors

TERMINAL OBJECTIVE(S):

33.4.64 When the student completes this lesson (s)he will be able to IDENTIFY the schematic symbols, construction, operating characteristics and methods for handling and testing field-effect transistor devices by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson (s)he will be able to:

33.4.64.1 IDENTIFY the schematic symbol, construction, and operating characteristics of N-channel and P-channel JFET devices by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.4.64.2 DEFINE "pinch-off" voltage as it applies to JFET operation by selecting the correct statement from a choice of four. 100% accuracy is required.

33.4.64.3 IDENTIFY the schematic symbol, construction, and operating characteristics of single-gate and dual-gate MOSFET devices by selecting the correct statement or schematic symbol from a choice of four. 100% accuracy is required.

33.4.64.4 IDENTIFY the proper methods and equipment to use when handling and troubleshooting FET devices by selecting the correct statement from a choice of four. 100% accuracy is required.

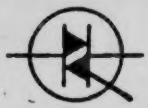
PROGRESS CHECK

LESSON 4

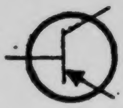
Field Effect Transistors

1. Which of the following symbols represents a JFET?

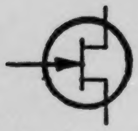
a.



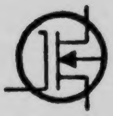
b.



c.



d.



2. A P-channel JFET has a solid bar made of (N/P) type material and a gate made of (N/P) type.

3. In an N-channel JFET, a decrease in negative voltage applied to the gate will cause the cross-sectional area of the channel to (increase/decrease), the source-to-drain resistance to (increase/decrease), and current flow through the JFET to (increase/decrease).

4. When "pinchoff" gate voltage is reached in the operation of a JFET, the depletion region is (large/small), channel resistance is (high/low), and drain current is (increased to maximum/reduced to zero).

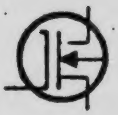
5. Rank the following devices in terms of the highest to lowest input impedance: JFETs, MOSFETs, and bipolar transistors.

highest input impedance ____________

next highest ____________

lowest ____________

6. What type of MOSFET is represented by this schematic symbol?



a. dual-gate, N-channel
b. single-gate, N-channel
c. dual-gate, P-channel
d. single-gate, P-channel

7. In MOSFETs, the gate material is made of

   a. N-type material
   b. P-type material
   c. silicon oxide (SiO_2)
   d. metal

8. The high input impedance of a MOSFET is possible because there is (a PN junction/total electrical isolation) between the gate and the (substrate material/source-drain channel).

9. When, if ever, should the shorting ring on a replacement MOSFET be removed?

   a. Just before installation.
   b. Just after installation.
   c. Never.

10. FET circuit measurements should be made using a (low/high) impedance (ammeter/voltmeter/ohmmeter).

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY AND FEEL READY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

MODULE

THIRTY FOUR

LINEAR INTEGRATED CIRCUITS

STUDENT'S GUIDE

JULY 1980

SUMMARY
LESSON 1

Introduction To Linear Integrated Circuits

Linear Integrated Circuits (linear IC's) are devices that integrate (combine) discrete (single) components into one package.

Most linear IC's are amplifiers. Their outputs will be proportional to their inputs. The internal circuitry is complete with very few required external components. Feedback networks, compensation networks, and LC tanks are added where needed.

The size of the IC is made up mostly of packaging materials; the actual circuit is a paper-thin wafer of silicon called the substrate (see Figure 1).

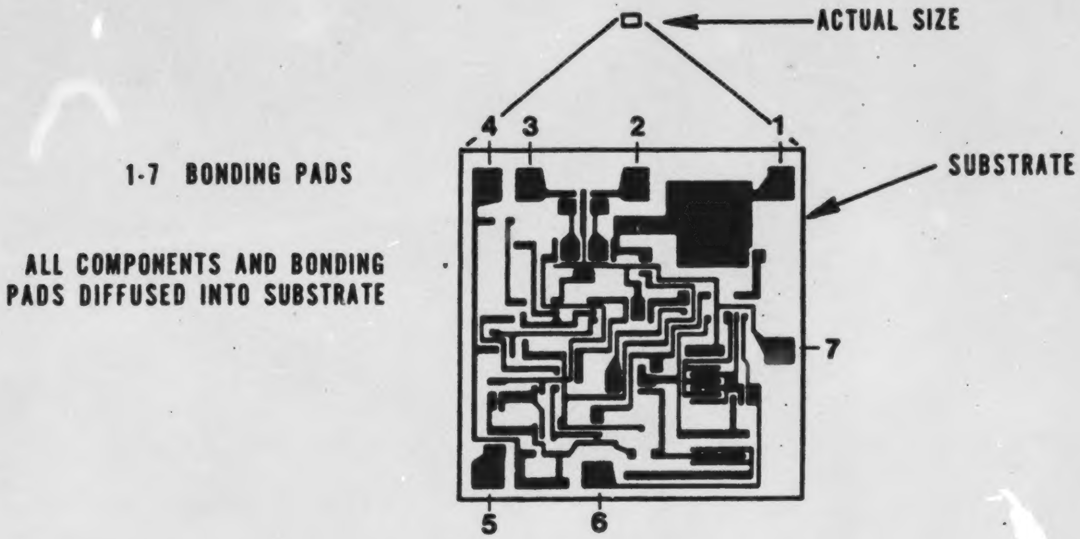

ACTUAL SIZE
4
3
2
1
SUBSTRATE
1-7 BONDING PADS
ALL COMPONENTS AND BONDING PADS DIFFUSED INTO SUBSTRATE
7
5
6

Figure 1

MAGNIFIED VIEW OF AN IC CHIP

The circuit's components are formed by a diffusion process (forcing molecules of other materials into the silicon). The completed circuit is called an "IC Chip". The IC chip is then mounted in a rugged package, like those shown in exploded views in Figure 2.

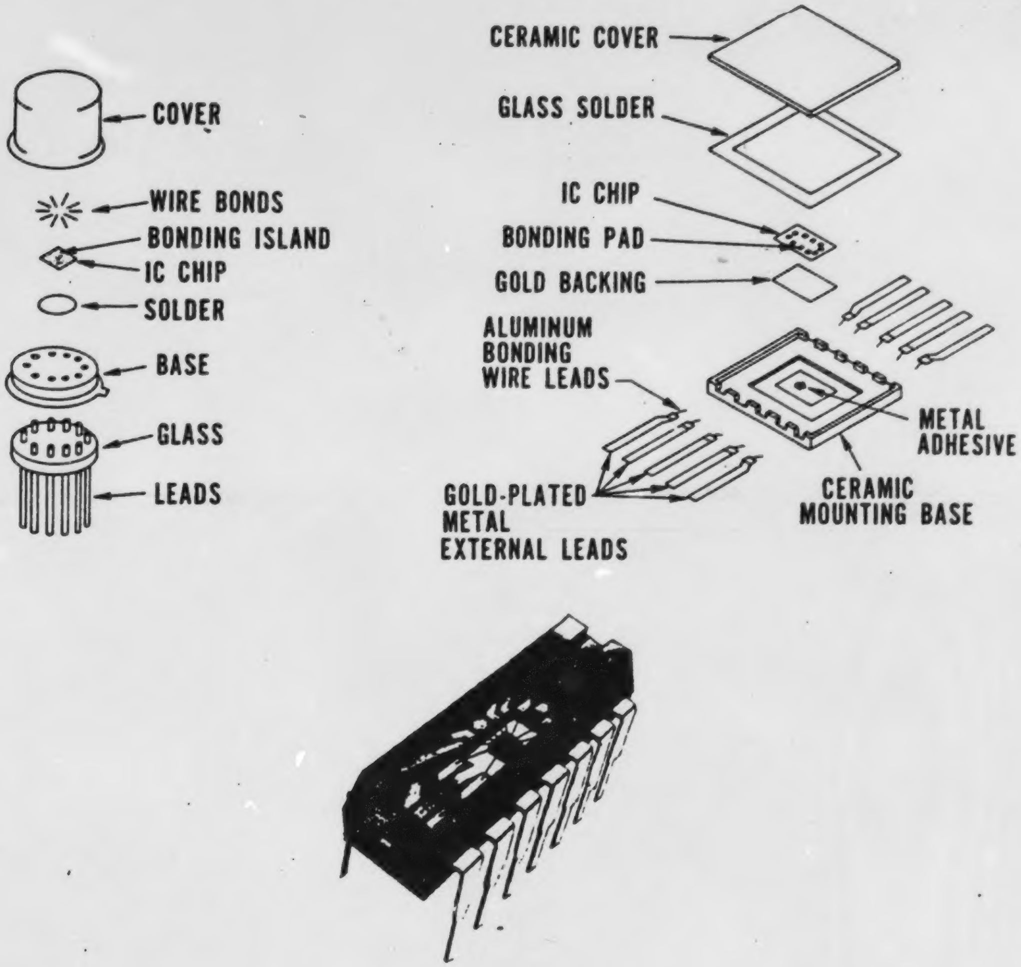

COVER
WIRE BONDS
BONDING ISLAND
IC CHIP
SOLDER
BASE
GLASS
LEADS
CERAMIC COVER
GLASS SOLDER
IC CHIP
BONDING PAD
GOLD BACKING
ALUMINUM BONDING WIRE LEADS
METAL ADHESIVE
GOLD-PLATED METAL EXTERNAL LEADS
CERAMIC MOUNTING BASE

Figure 2

VARIOUS IC PACKAGES

The IC chip is soldered or cemented to a base and fine gold or aluminum wires are bonded to pads on the IC chip as shown in Figure 3.

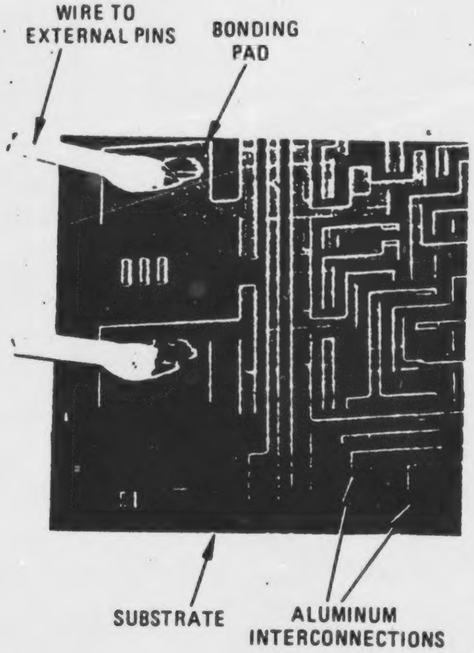

WIRE TO EXTERNAL PINS
BONDING PAD
SUBSTRATE
ALUMINUM INTERCONNECTIONS

Figure 3

IC LEAD BONDING

The bonded wires are attached to the external pins, the cover is installed, and the IC package is then hermetically sealed. A hermetic seal is a seal that will not allow air, dust, or moisture to pass.

The result is a small, rugged device (see Figure 4).

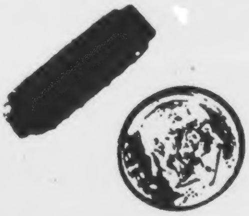


Figure 4

IC RELATIVE SIZE

Even though installed IC's are very rugged devices, they may be damaged while being handled. One of the things that can destroy an IC circuit is the static electricity that builds up on your body. To prevent static electricity from damaging the IC, ground yourself for a couple of seconds before handling the IC. An IC's shipping wrapper is made of a material designed to protect the IC from static electricity. Therefore, you should keep an IC in its shipping wrapper until you are ready to install it in a piece of equipment.

An IC may be mounted by soldering it onto a printed circuit board. The pads on the board should be spaced to accept the IC, but sometimes the IC leads do not line up with the holes in the pads. When this problem occurs, you must carefully bend the IC leads to make them line up properly. To do this you should use two small needlenose pliers: one to support the IC's leads, the other to make the bend (see Figure 5).

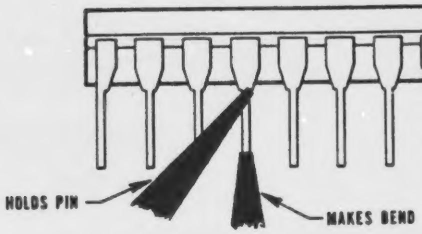


Figure 5

STRAIGHTENING IC LEADS

You must be careful not to bend a lead where it enters the IC as you do not want to break the hermetic seal. If this seal did break, the IC circuit might eventually short out from dust and moisture which could enter through the break.

Plug-in type IC's are attached to a printed circuit board by plugging them into an IC socket (see Figure 6).

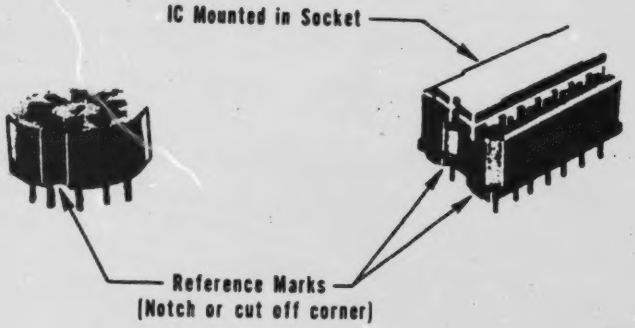


Figure 6

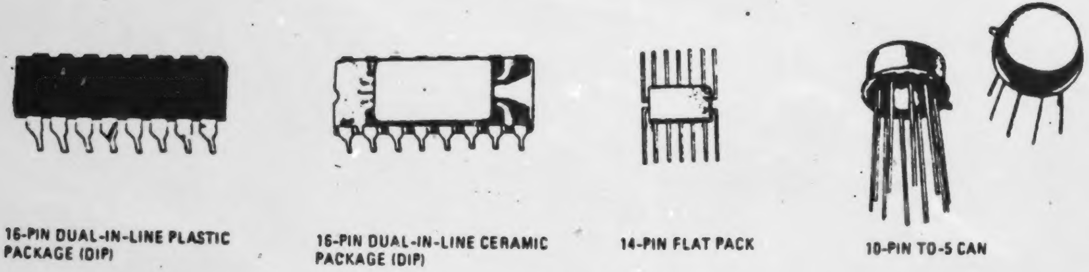
IC SOCKETS

To remove an IC from its socket, the equipment must first be deenergized. Removal is accomplished through the use of an IC removal tool called a DIP puller or package puller. If this tool is unavailable, grasp the IC between your thumb and forefinger and gently rock the IC out of the socket.

To put an IC into a socket, first make sure the pins line up with the socket's holes. If they don't, line up the leads by bending them with the two needle-nose pliers. Next, line up the reference mark on the IC (a notch, dot, impression, hole, or tab) with the socket's reference mark (a notch or cut off corner). Then, with the IC's leads lined up with the socket's holes, and the equipment deenergized, hold the IC between your thumb and forefinger and gently rock it into place.

One last handling precaution: Be carfeul not to drop or strike an IC; either the hermetic seal or one of the fine internal connecting wires may be broken.

IC's are manufactured in various package shapes (see Figure 7).


16-PIN DUAL-IN-LINE PLASTIC PACKAGE (DIP)

16-PIN DUAL-IN-LINE CERAMIC PACKAGE (DIP)

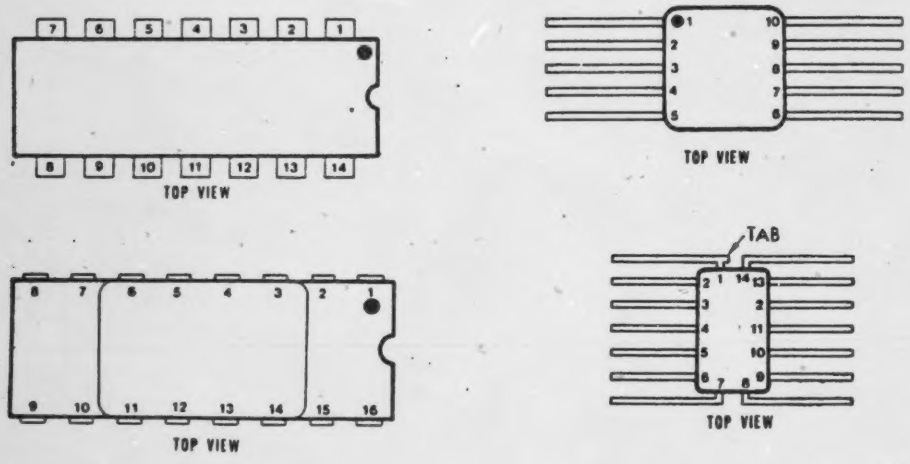
14-PIN FLAT PACK

10-PIN TO-5 CAN

Figure 7

IC CASE STYLES

Each IC has a reference mark. The dual-in-line package or DIP (both plastic and ceramic) and the flat pack will have a notch, dot or impression on the package. When viewed from the top, pin 1 will be the first pin in a counterclockwise direction directly next to the reference mark. Pin 1 may also be marked directly by a hole or notch in it or a tab on it (in this case pin 1 is the counting reference). When viewed from the top, all other pins are numbered consecutively in a counterclockwise direction from pin 1 (see Figure 8).


7 6 5 4 3 2 1
8 9 10 11 12 13 14
TOP VIEW
1 2 3 4 5
10 9 8 7 6
TOP VIEW
8 7 6 5 4 3 2 1
9 10 11 12 13 14 15 16
TOP VIEW
TAB
1 2 3 4 5 6 7 8 9 10 11 12 13 14
TOP VIEW

DIP Packages

Flat Pack Packages

Figure 8

IC PIN NUMBERING

The TO-5 can has a tab for the reference. When numbering the leads you must view the TO-5 can from the bottom. Pin 1 will be the first pin in a clockwise direction from the tab. All other pins will be numbered consecutively in a clockwise direction from pin 1 (see Figure 9).*

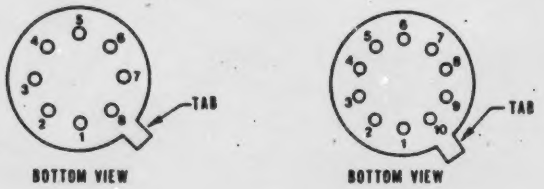

5
4
6
3
7
2
1
8
TAB
BOTTOM VIEW
6
5
7
4
8
3
9
2
1
10
TAB
BOTTOM VIEW

Figure 9

IC PIN NUMBERING

The schematic symbol for a linear IC is a triangle (most common) or a rectangle, as shown in Figure 10.

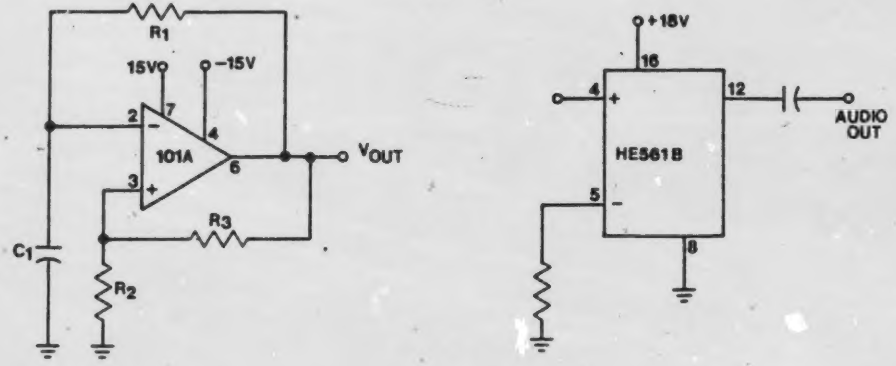

R1
15V
−15V
7
4
2
−
101A
6
3
+
VOUT
R3
C1
R2
+18V
16
4
+
12
AUDIO OUT
HE561B
5
−
8

Figure 10

IC SCHEMATIC SYMBOLS

The IC's type number will be printed in the middle of the circuit symbol (101A, HE 561 B). The pin numbers will be printed outside the schematic symbol. The (+) and (-) in the triangle or rectangle indicate a non-inverting input (+) and an inverting input (-). These inputs plus the outputs and power supply connections are the only pin functions that are identified. To find the function of the other pins you must use a data sheet.

---

* Although this is the accepted standard, there are exceptions.

A data sheet may be just a schematic of the IC's internal circuitry with the pin functions labeled (see Figure 11).

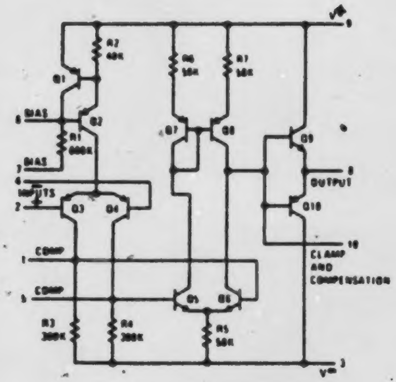

V+
9
R2
40K
R6
10K
R7
10K
Q1
Q2
8
BIAS
R1
600K
7
BIAS
4
INPUTS
2
Q3
Q4
Q7
Q8
Q9
8
OUTPUT
Q10
10
CLAMP
AND
COMPENSATION
1
COMP
5
COMP
Q5
Q6
R3
300K
R4
300K
R5
50K
3
V-

Figure 11

LH0001 SCHEMATIC DIAGRAM

The data sheet may also be a Manufacturer's Data Sheet as shown in Figure 12 on the next page. This data sheet is for a type of linear IC called an operational amplifier.

LH101 LH201 OPERATIONAL AMPLIFIER

FOR AMPLIFIERS, VOLTAGE COMPARATORS, LOW DRIFT SAMPLE-AND-HOLD

Features

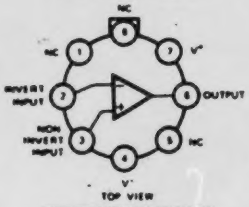
- Low Offsets and Temperature Drift
- Internal 30 pF Capacitor for Frequency Compensation
- Operation from ±5 to ±20 Volt Power Supplies
- Low Current Drain, 1.8 mA at ±20 Volts Typical
- Continuous Short-Circuit Protection
- No Latch Up When Common Mode Range Is Exceeded
- Same Pin Configuration as 709 Amplifier

Description

The LH101/LH201 is stable for all feedback configurations, even with capacitive loads, with no external compensation capacitors. Low power dissipation permits high voltage operation across the full temperature range.

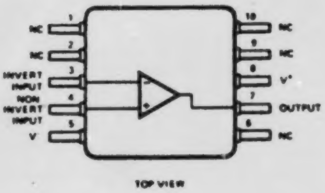
PIN CONFIGURATIONS

Metal Can Package


NC
1
2
3
4
5
6
7
8
NC
V⁺
INVERT INPUT
OUTPUT
NON INVERT INPUT
NC
V⁻
TOP VIEW
NOTE PIN 4 CONNECTED TO CASE

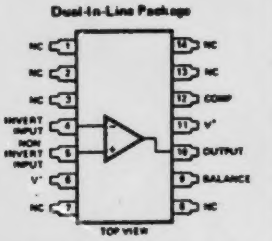
ORDER NUMBERS: LH101H OR LH201H
SEE PACKAGE 1

Flat Package


NC
NC
INVERT INPUT
NON INVERT INPUT
V⁻
1
2
3
4
5
10
9
8
7
6
NC
NC
V⁺
OUTPUT
NC
TOP VIEW

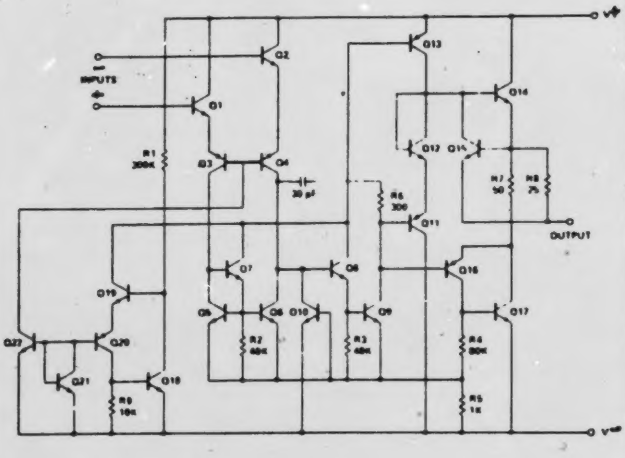
ORDER NUMBERS: LH101F OR LH201F
SEE PACKAGE 4

Dual-In-Line Package


NC 1
NC 2
NC 3
INVERT INPUT 4
NON INVERT INPUT 5
V⁻ 6
NC 7
14 NC
13 NC
12 COMP
11 V⁺
10 OUTPUT
9 BALANCE
8 NC
TOP VIEW

ORDER NUMBERS: LH101D OR LH201D
SEE PACKAGE 11

SCHEMATIC DIAGRAM


V⁺
V⁻
INPUTS
Q1
Q2
Q3
Q4
30 pF
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
Q13
Q14
Q15
Q16
Q17
Q18
Q19
Q20
Q21
Q22
R1 300K
R2 40K
R3 40K
R4 80K
R5 1K
R6 300
R7 50
R8 75
R9 10K
OUTPUT

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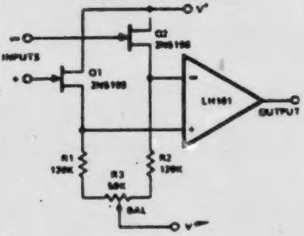
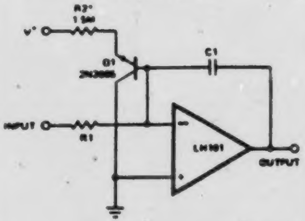
TYPICAL APPLICATIONS

FET Operational Amplifier


V⁺
INPUTS
Q1 2N5199
Q2 2N5199
LH101
OUTPUT
R1 120K
R2 120K
R3 50K
BAL
V⁻

Integrator with Bias Current Compensation


R2* 1.5M
V⁺
Q1 2N2605
C1
INPUT
R1
LH101
OUTPUT

*SELECT FOR ZERO INTEGRATOR DRIFT

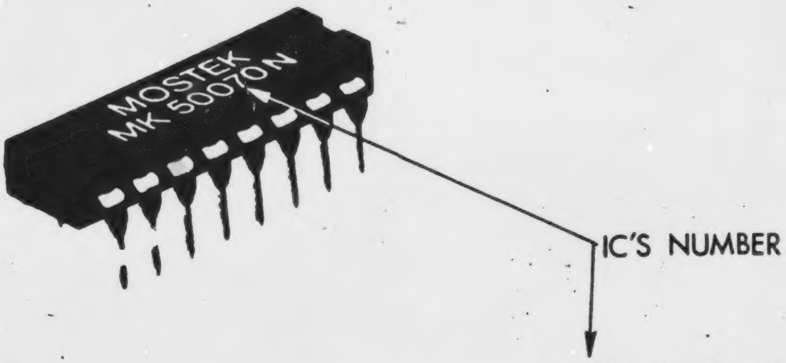
Reprinted by permission of Siliconix Incorporated. *NC - not connected internally

Figure 12

IC DATA SHEET

The manufacturer's data sheet will have either the pin configurations section, a schematic diagram, or both.

The required data sheets will be supplied with the equipment manuals. To select the correct data sheet for an IC, simply match the IC's type number, printed on the IC package or in the IC's circuit symbol, to the data sheet's type number (see Figure 13).


MOSTEK
MK 50070 N
IC'S NUMBER

PRELIMINARY

MK 50070 N

CMOS Oscillator and Divider

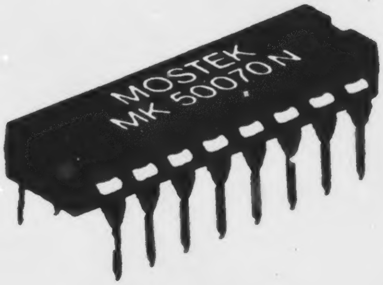
MOSTEK

FEATURES:

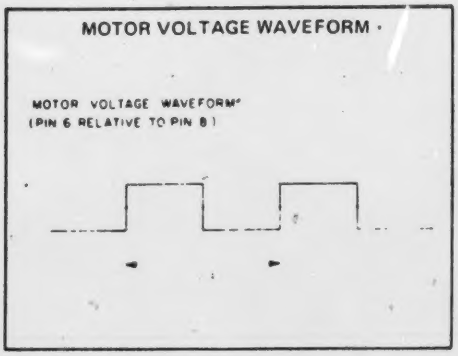
- Low Power Dissipation
- 4-18 Volt Operating Range
- Internal Zener Regulation
- Internal Oscillator

DESCRIPTION:

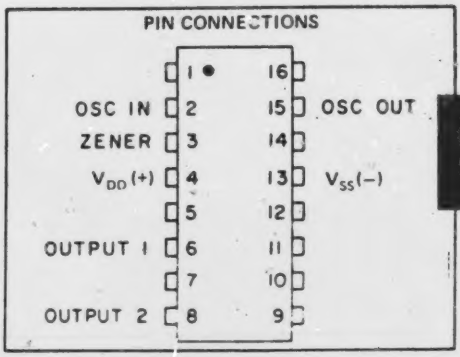
The MOSTEK 50070 circuit is an oscillator and divider circuit for specialized applications. An external quartz crystal determines the oscillator frequency and the chip divides this frequency by 49152. The output is buffered by a 4 transistor bridge.


MOSTEK
MK 50070 N

MOTOR VOLTAGE WAVEFORM



PIN CONNECTIONS


1
16
OSC IN 2
15 OSC OUT
ZENER 3
14
V_{DD}(+) 4
13 V_{SS}(−)
5
12
OUTPUT 1 6
11
7
10
OUTPUT 2 8
9

Special Products

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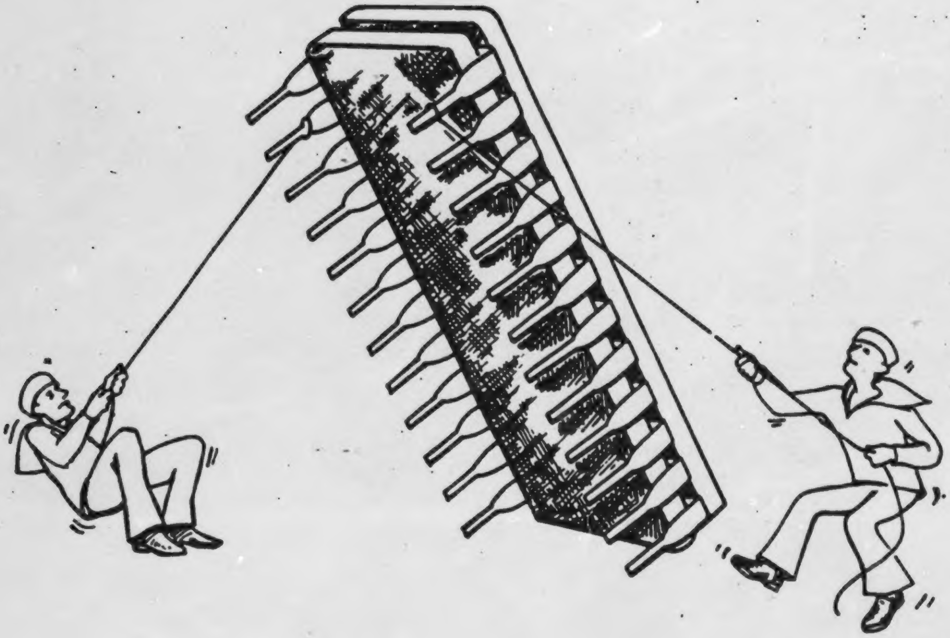
Figure 13

IC DATA SHEET

The information covered in this lesson applies to all ICs. ICs require a little more care in handling than transistors, but once installed in a circuit board they are very rugged and can operate for years without circuit failure.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.



PROGRESS CHECK
LESSON 1

Introduction To Linear Integrated Circuits

TERMINAL OBJECTIVE(S):

34.1.65 When the student completes this lesson (s)he will be able to IDENTIFY basic characteristics of linear integrated circuits to include definitions of terms, proper handling procedures, pin numbering systems and functions by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson, (s)he will be able to:

34.1.65.1 IDENTIFY the basic characteristics of a linear integrated circuit by choosing the correct set of characteristics from a choice of four. 100% accuracy is required.

34.1.65.2 IDENTIFY proper handling procedures for integrated circuits by choosing the correct statement from a choice of four. 100% accuracy is required.

34.1.65.3 IDENTIFY the set of integrated circuit (IC) packages that have their leads properly numbered, given IC package drawings, by choosing the correct drawing or pin number from a choice of four. 100% accuracy is required.

34.1.65.4 DETERMINE the function of a given pin on an IC, given the IC's part number, data sheet, package type and pin number, by selecting the correct statement from a choice of four. 100% accuracy is required.

34.1.65.5 IDENTIFY the proper procedures for soldering and replacing ICs by selecting the correct statement from a choice of four. 100% accuracy is required.

162

PROGRESS CHECK
LESSON 1

Introduction To Linear Integrated Circuits

1. Integrated circuits replace (only one/many) component(s).

2. A linear IC produces an output signal that can be ____________________ the input signal.

   a. an amplified version of
   b. in phase with
   c. 180° out of phase with
   d. any of the above

3. The hermetic seal on an IC will not protect it from

   a. moisture.
   b. static electricity.
   c. dust.

4. The shipping wrapper (will/will not) protect an IC from static electricity.

5. When bending the leads of an IC you (do/do not) need two needlenose pliers.

6. When removing or installing an IC, the equipment containing the IC (must/need not) be deenergized to prevent damage to the IC.

7. Before an IC is installed into its socket, its reference mark must be ________________________ the sockets reference mark.

   a. lined up with
   b. one pin in a counterclockwise direction from
   c. lined up at the opposite end from
   d. one pin in a clockwise direction from

8. The abbreviation "DIP" means "__________________ Package".

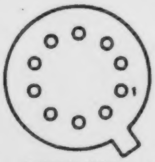
   a. Durable Integrated
   b. Dual-In-line
   c. Differential Integrated
   d. Discrete Integrated

9. When viewed from the top, the pins of the DIP and flat pack are numbered consecutively in a (clockwise/counterclockwise) direction from the reference mark.

10. When viewed from the bottom, the pins of the TO-5 package are numbered consecutively in a (clockwise/counterclockwise) direction from the reference mark.

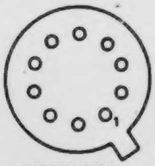
11. Which illustration shows the correct labeling of pin 1 on the TO-5 package viewed from the bottom?

a.



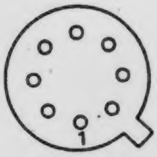
BOTTOM VIEW

b.



BOTTOM VIEW

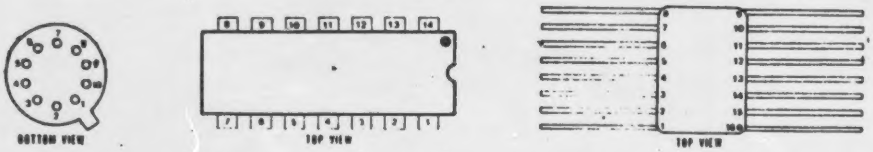
c.



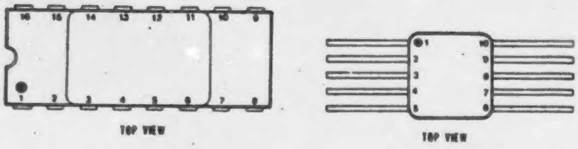
BOTTOM VIEW

12. In which of the following set of illustrations are the leads of the IC packages labeled correctly.

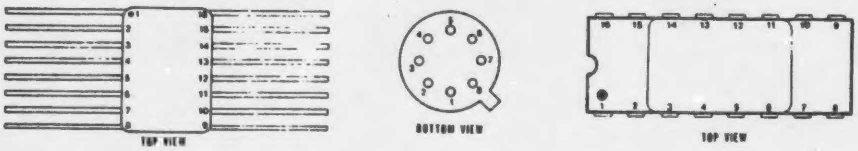
a.


BOTTOM VIEW
TOP VIEW
TOP VIEW

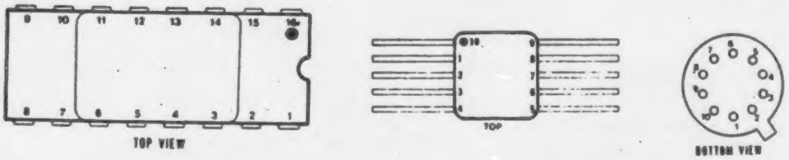
b.


TOP VIEW
TOP VIEW
BOTTOM VIEW

c.


TOP VIEW
BOTTOM VIEW
TOP VIEW

d.


TOP VIEW
TOP
BOTTOM VIEW

13. In an IC's schematic symbol, its type number will appear (in the middle/ or the outside) of the symbol.

14. Refering to this data sheet, pin 8 of the TO-5 package is the __________ connection.

a. + Vcc
b. output
c. NC
d. ground

LINEAR INTEGRATED CIRCUITS

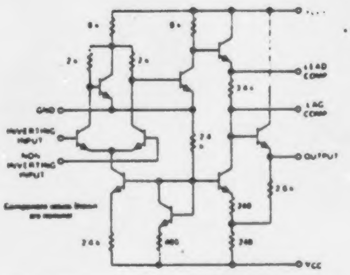
TYPES SN52702A, SN52702, SN72702 GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 7311460 MARCH 1971 · REVISED [illegible]

SN52702A features

- Open-Loop Voltage Amplification . . . 3600 Typ
- Designed to be Interchangeable With Fairchild μA702A
- CMRR . . . 100 dB Typ

schematic

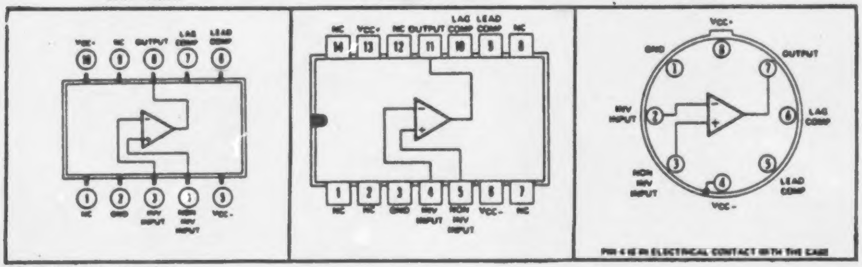

GND
INVERTING INPUT
NON INVERTING INPUT
LEAD COMP
LAG COMP
OUTPUT
VCC-

description

The SN52702A, SN52702 and SN72702 circuits are high-gain, wideband operational amplifiers, each having differential inputs and single-ended emitter-follower outputs. Provisions are incorporated within the circuit whereby external components may be used to compensate the amplifier for stable operation under various feedback or load conditions. Component matching, inherent in silicon monolithic circuit-fabrication techniques, produces an amplifier with low-drift and low-offset characteristics. The SN52702A is an improved version of the SN52702. These amplifiers are particularly useful for applications requiring transfer or generation of linear and non-linear functions up to a frequency of 30 MHz.

The SN52702A and SN52702 circuits are characterized for operation over the full military temperature range of −55°C to 125°C. The SN72702 circuit is characterized for operation over the temperature range of 0°C to 70°C.

terminal assignments


FA FLAT PACKAGE (TOP VIEW)

J OR N DUAL-IN-LINE PACKAGE (TOP VIEW)

TO-5
L PLUG-IN PACKAGE (TOP VIEW)

VCC+
NC
OUTPUT
LAG COMP
LEAD COMP
NC
GND
INV INPUT
NON INV INPUT
VCC-
NC VCC+ NC OUTPUT LAG COMP LEAD COMP NC
14 13 12 11 10 9 8
1 2 3 4 5 6 7
NC NC GND INV INPUT NON INV INPUT VCC- NC
VCC+
GND
OUTPUT
INV INPUT
LAG COMP
NON INV INPUT
LEAD COMP
VCC-
PIN 4 IS IN ELECTRICAL CONTACT WITH THE CASE

NC—No internal connection

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15. When replacing soldered-in ICs on a printed circuit board, the technician should use the (largest/smallest) soldering iron possible with a (grounded/ungrounded) tip.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

SUMMARY
LESSON 2

IC Operational Amplifiers

An IC Operational Amplifier (opamp) is a class "A" amplifier which has two inputs and one output. One of the inputs will have the signal we wish to amplify applied to it. The other input will be connected to a resistor that will develop bias for the IC. The resulting output will be the input multiplied by the gain of the circuit.

Various schematic symbols for an IC opamp are shown in Figure 1.

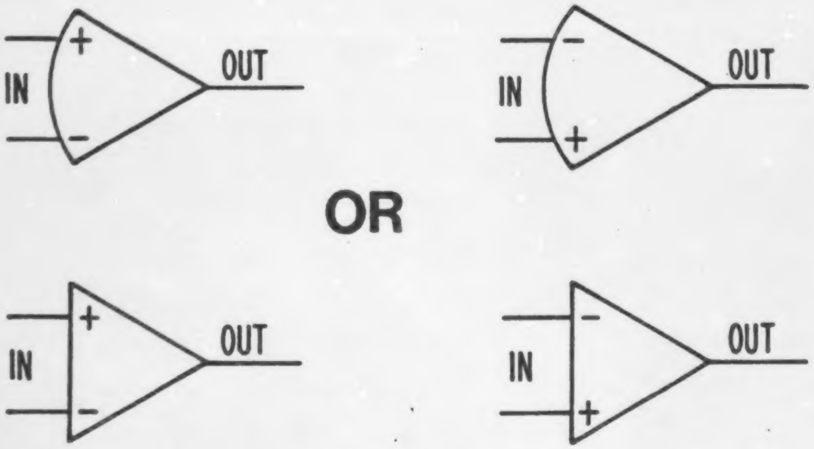


Figure 1

OPAMP SCHEMATIC SYMBOLS

IC opamps are used as either inverting or non-inverting amplifiers. Figure 2 shows an inverting IC opamp amplifier circuit.

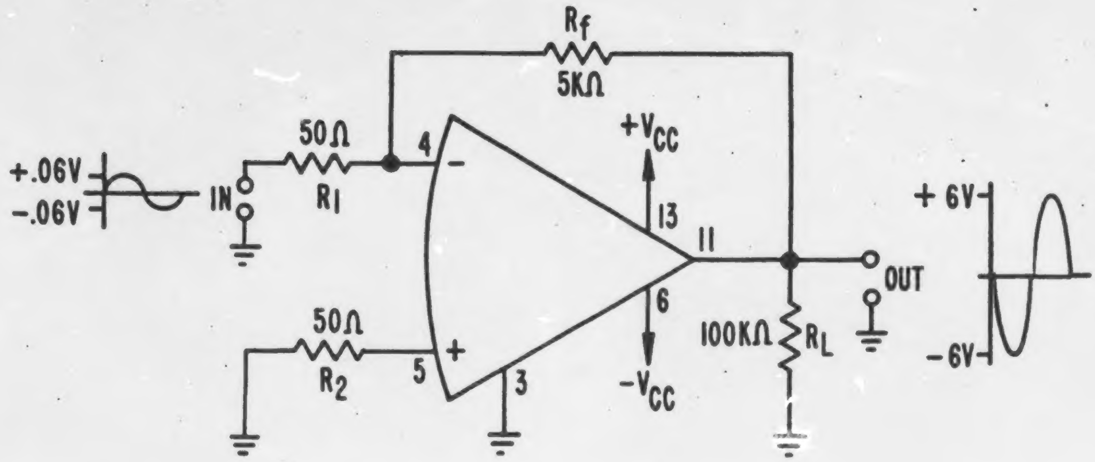

R_f
5KΩ
50Ω
4
−
$+V_{CC}$
+.06V
−.06V
IN
R_1
13
11
+ 6V
OUT
6
50Ω
+
100KΩ
R_L
− 6V
R_2
5
3
$-V_{CC}$

Figure 2

INVERTING OPAMP

In Figure 2, R1 is the input resistor, R2 the bias resistor, Rf the feedback resistor and RL the load resistor. Figure 3 shows a non-inverting IC opamp amplifier circuit.

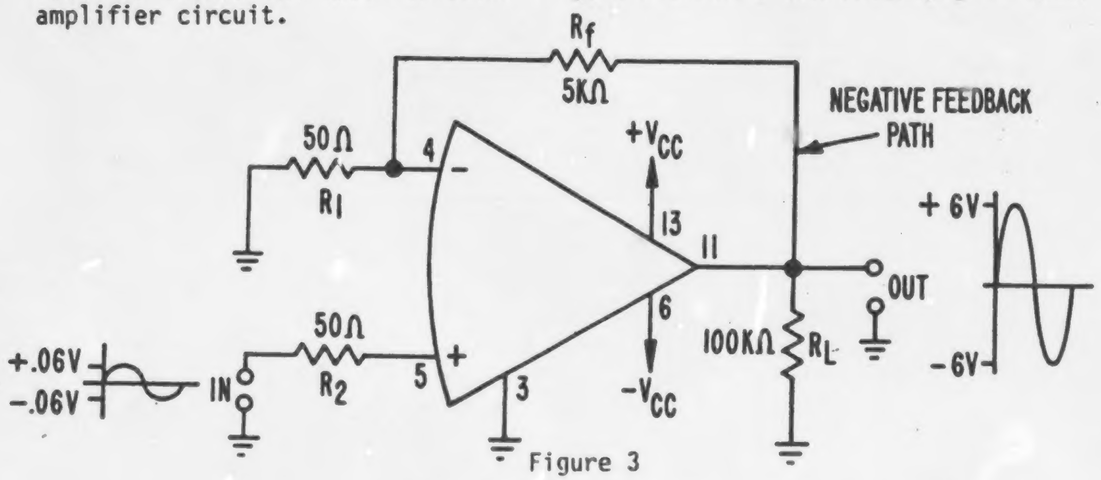

R_f
5KΩ
NEGATIVE FEEDBACK PATH
50Ω
4
−
$+V_{CC}$
R_1
13
+ 6V
11
OUT
6
50Ω
100KΩ
R_L
+.06V
+
− 6V
−.06V
IN
R_2
5
3
$-V_{CC}$

Figure 3

NON-INVERTING OPAMP

This circuit is the same as the inverting amplifier circuit except that the input and bias connections are reversed. Now the input resistor is R2 and the bias resistor is R1.

Operational amplifiers have extremely high gain. Both the inverting and the non-inverting IC opamp amplifier circuits use negative feedback to stabilize the output signal and prevent oscillation. The inverting amplifier has a feedback signal that is 180° out of phase with the input signal and, since both signals are applied to the same point, negative feedback is directly provided. See Figure 4.

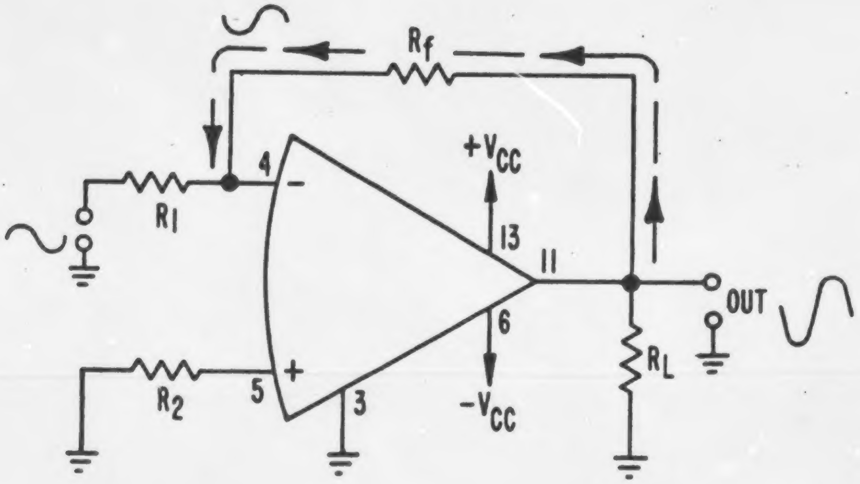


Figure 4

INVERTING IC OPAMP FEEDBACK PATH

The non-inverting amplifier has a feedback signal that is in phase with the input signal which would indicate the use of positive feedback. However, the feedback signal is applied to the inverting input where it is inverted inside the IC. See Figure 5.

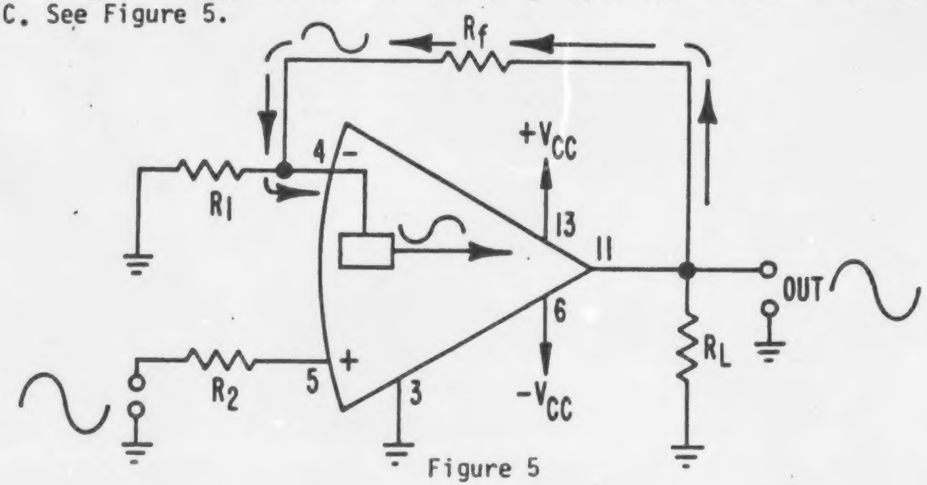


Figure 5

NON-INVERTING IC OPAMP FEEDBACK PATH

The feedback signal on the inverting input terminal (-) acts in opposition to the input signal on the non-inverting terminal (+).

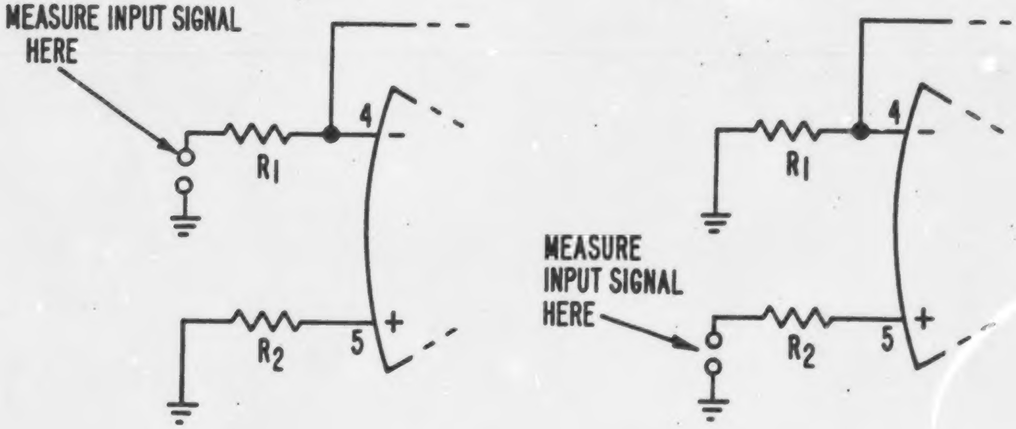
Since the inverted feedback is 180° out-of-phase with the input signal, negative feedback is being used.

To measure the input signal you would use an oscilloscope. But, you must not measure the input signal on the input pin of the IC.

With the inverting amplifier, the negative feedback and the input signal are applied to the IC's input. Since the two signals are 180° out-of-phase, the resultant signal is too small to measure.

With the non-inverting amplifier, the input signal at the IC's input may be smaller than the actual input signal due to the voltage drop across the input resistor.

Therefore you must measure the input signal to either amplifier (inverting or non-inverting) at the points indicated in Figure 6.



INVERTING OP AMP NON-INVERTING OPAMP

Figure 6

MEASURING OP AMP INPUT SIGNALS

In both the inverting and non-inverting amplifiers, the gain is controlled by the ratio of Rfeedback to Rin or

$$\text{Gain} \simeq \frac{R_{feedback}}{R_{in}}$$

The symbol "≃" means "approximately equal to". This gain is approximate because there are other factors at an engineering level to take into consideration. However, the gain determined by this formula will be close enough to the actual amount for our purposes.

Since the gain of an amplifier is the number of times the input signal is multiplied,

$$\text{Vout} \simeq \text{Vin} \frac{\text{Rfeedback}}{\text{Rin}}$$

(NOTE: This formula may be used regardless of how the input is stated, i.e., peak-to-peak, peak, or RMS. However, the output must be stated in the same terms).

The Vout formula is a good troubleshooting aid. With it you can determine whether the output signal has the correct amplitude or not.

You cannot normally test the IC when the amplifier circuit has a bad output signal. However, you can check the supply voltages to the IC and the components external to the IC.

To check supply voltages to the IC, a VOM or VTVM may be used. The IC opamp requires both positive (+VCC or V+) and negative (-VCC or V-) voltages, most commonly between 6 volts and 18 volts. See Figures 4 and 5. The equipment manuals will indicate the correct voltages and the pin numbers where the voltages are applied.

To check resistance of the external components, a VOM may be used. However, multiple current paths through the IC will cause false readings across the external components. Also, the IC can be damaged by the current from the meter; therefore, the IC must be isolated from the components under test. If the IC is plugged into an IC socket, observing proper handling precautions, unplug the IC. If the IC is soldered into the circuit board, you must unsolder and lift out one lead of the component under test to isolate that component from the IC and other circuit components. Therefore, you should have some idea of the possible cause of a symptom to eliminate unnecessary soldering.

To check the output signal of the IC, an oscilloscope is used. Place the oscilloscope probe on the output pin of the IC. The Vout formula will help you determine if the signal amplitude is correct. Remember, when you check the IC opamp amplifier circuit, you must first check the signal input, the DC voltage inputs, and all external components before considering the IC to be faulty.

IC handling precautions are identical with those for MOS devices and are shown in Figure 7.

NOTICE

SPECIAL HANDLING OF MOS DEVICES

The MOS metal oxide semiconductor devices have a fairly high input resistance making them subject to damage from charges of static electricity through improper handling. The thin layer of oxide can be damaged from discharges of static electricity or improper handling in or out of circuit. The damage may be apparent immediately or may show up only after a short operating time. To avoid possible damage, the following procedures should be followed when handling or testing these devices.

1. The use of synthetic clothing such as nylon should be avoided as this will generate static charges. Dry weather (relative humidity less than 30%) also tends to increase static buildup.
2. Keep the leads of the device in contact with a conducting material or shorted, except when testing, inserting or removing from the circuit.
3. A wrist strap with a megohm resistor in series to common ground should be worn by the technician when inserting, removing or testing MOS devices.
4. Do not remove or insert an MOS device with the power to the circuit or test instrument "ON".
5. Do not apply or inject test signals into the circuit when an MOS device is used with the circuit power "OFF".
6. Do not turn the circuit power "ON" with an MOS device removed from the circuit. Charges can build up causing possible damage when the device is replaced in the circuit.
7. Soldering iron tips, metal bench tops, test equipment and tools should be grounded to a common ground along with the chassis of the set being serviced.
8. Soldering guns should not be used in MOS circuits; AC line leakage from the gun tip could cause damage to an MOS device.
9. Do not apply heat for longer than 10 seconds or closer than 1/16 of an inch to any MOS device when soldering. Use of a heat sink is recommended to prevent damage to the advice.
10. Use the lowest wattage soldering iron possible when removing or inserting MOS devices on printed circuit boards.

Figure 7

IC HANDLING PRECAUTIONS

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, YOU MAY TAKE THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 2

IC Operational Amplifiers

TERMINAL OBJECTIVE(S):

34.2.66 When the student completes this lesson (s)he will be able to IDENTIFY basic functional characteristics of operational amplifiers to include using gain formulas to calculate the gain of inverting and non-inverting circuit configurations and listing correct troubleshooting methods by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

When the student completes this lesson (s)he will be able to:

34.2.66.1 IDENTIFY the functional characteristics of an IC operational amplifier by selecting the correct statement from a choice of four. 100% accuracy is required.

34.2.66.2 IDENTIFY inverting and non-inverting opamp circuit configurations, given schematic diagrams, by selecting the correct name or diagram from a choice of four. 100% accuracy is required.

34.2.66.3 IDENTIFY the formulas used for computing output voltage in an IC operational amplifier by selecting the correct formula from a choice of four. 100% accuracy is required.

34.2.66.4 CALCULATE the gain on an operational amplifier circuit given a schematic diagram and necessary circuit values by selecting the correct gain value from a choice of four. 100% accuracy is required.

34.2.66.5 IDENTIFY proper troubleshooting methods for a given IC opamp circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

PROGRESS CHECK
LESSON 2

IC Operational Amplifiers

1. An IC opamp operates class

   a. A
   b. AB
   c. B
   d. C

2. An IC opamp is a/an

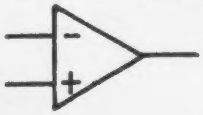
   a. frequency multiplier.
   b. oscillator.
   c. amplifier.
   d. frequency divider.

3. An IC opamp's two inputs (inverting or non-inverting) produce ____________ amplifier output(s).

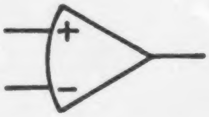
   a. 1
   b. 2
   c. 3
   d. 4

4. The schematic symbol(s) for an IC opamp is/are

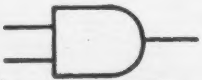
   a.



   b.



   c.



   d. either a or b.

5. The gain formula for an IC opamp is Gain = ______________.

   a. $\frac{\text{Rin}}{\text{Rfeedback}}$

   b. $\frac{\text{Rfeedback}}{\text{RL}}$

   c. $\frac{\text{Rfeedback}}{\text{Rin}}$

   d. $\frac{\text{Rin}}{\text{RL}}$

6. The formula for the output voltage of an IC opamp amplifier circuit is Vout = ___________.

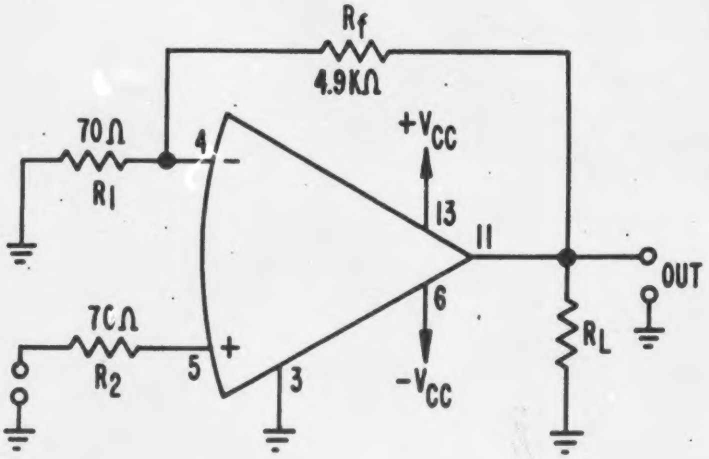
   a. $\text{Vin}\left(\frac{\text{Rin}}{\text{Rfeedback}}\right)$

   b. $\text{Vin}\left(\frac{\text{Rfeedback}}{\text{Rin}}\right)$

   c. $\left(\frac{\frac{\text{Rfeedback}}{\text{Rin}}}{\text{Vin}}\right)$

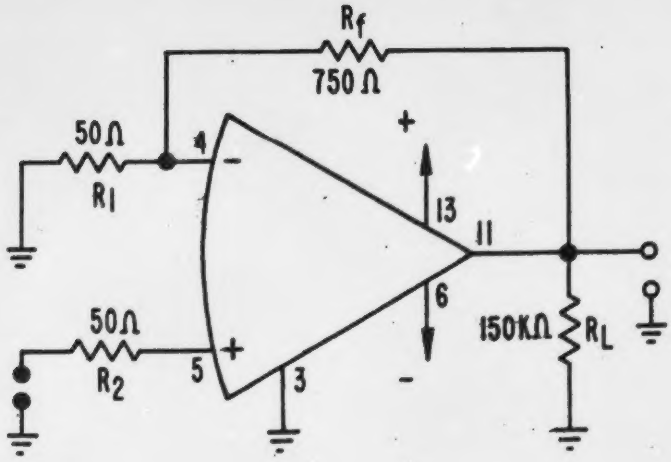
   d. $\left(\frac{\text{Vin}}{\frac{\text{Rfeedback}}{\text{Rin}}}\right)$

7. The gain of the circuit below is



   a. 70
   b. 1.43
   c. 7
   d. 2.1

8. In the circuit below, with a .06 volt signal applied, the output signal would be _________ volts.



a. 004
b. 15
c. .67
d. .9

9. Both IC amplifier circuit configurations use _________ feedback.

a. negative
b. positive
c. neutral
d. regenerative

10. To check the input signal to an IC opamp circuit you (would/would not) put the oscilloscope probe on the IC's input pin.

11. The power supply required by an IC opamp is a/an _______voltage.

a. positive D.C.
b. negative D.C.
c. AC
d. both a and b

12. To make resistance checks of the external components of an IC opamp, the IC must be (isolated/in the circuit).

13. For the IC to be considered faulty in an IC opamp circuit, which condition(s) would check good?

    a. The input signal.
    b. The resistance of the external components.
    c. The IC's DC supply voltages.
    d. a, b, and c.

CHECK YOUR RESPONSES TO THIS PROGRAM CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGE, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

ANSWER SHEETS
FOR
MODULES
THIRTY TWO
THIRTY THREE
THIRTY FOUR

STUDENT'S GUIDE

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 1

Hartley Oscillators

QUESTION NO.	CORRECT ANSWER	NARRATIVE REF. PAGES	P.I. REF. FRAMES
1.	a	41	1-5
2.	c	41	1-5
3.	b	43	6-10
4.	c	44-45	6-10
5.	a	44-45	6-10
6.	c	47	11-16
7.	a	47	11-16
8.	b	47	11-16
9.	c	48	17-20
10.	d	48	17-20
11.	d	48	17-20
12.	b	48	17-20

ANSWER SHEET
FOR
JOB PROGRAM
LESSON 1

Hartley Oscillators

16. a. 18.56 MHz
    b. 118.56 MHz
    c. 107.86 MHz

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 2

RC Phase Shift Oscillator

Question No.	Correct Answer	References Narrative Page(s)	 P.I. Frame(s)
1.	c	87-88	1-2
2.	c	87-88	1-2
3.	a	87-88	1-2
4.	b	88-90	3-7
5.	b	88-90	3-7
6.	d	88-90	3-7
7.	a	88-90	3-7
8.	b	88-90	3-7
9.	a	88-90	3-7
10.	b	90-92	8-11
11.	b	90-92	8-11
12.	d	90-92	8-11
13.	c	92-93	12-17
14.	b	92-93	12-17
15.	a	92-93	12-17

ANSWER SHEET
FOR
JOB PROGRAM
LESSON 2

RC Phase Shift Oscillator

9a. 0.125 VDC
b. 1.15 msec.
c. 869 Hz.

17a. 1.15 msec.
b. yes

23a. 867 Hz.
b. yes

27a. Decreased

28a. Decreased

30a. Decreased

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 3

Wien-Bridge Oscillator

		REFERENCES	
QUESTION NO.	CORRECT ANSWER	Narrative Page	P.I. Frame
1.	a	131-132	1-4
2.	d	131-132	1-4
3.	c	131-132	1-4
4.	c	131-132	1-4
5.	d	133-135	5-11
6.	b	133-135	5-11
7.	d	136-139	12-17
8.	b	136-139	12-17
9.	a	140-141	12-17
10.	c	140-141	12-17

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 4
Blocking Oscillators

		REFERENCES	
QUESTION NO.	CORRECT ANSWER	Narative Ref. Pages	P.I. Ref. Frames
1.	d	185-186	1-6
2.	a	185-186	1-6
3.	c	185-186	1-6
4.	b	186-187	7-15
5.	a	186-187	7-15
6.	d	186-187	7-15
7.	d	188-193	16-21
8.	d	188-193	16-21
9.	d	193-196	16-21
10.	a	193-196	16-21

ANSWER SHEET
FOR
JOB PROGRAM
LESSON 4

Blocking Oscillators

8a. 746 Hz.
b. 0.28 msec.
c. 1.05 msec.

12a. 1.34 msec.
b. Yes

15a. .748 kHz or 748 Hz.
b. Yes

20a. Decreased
b. Decreased

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 5
Crystal Controlled Oscillators

QUESTION NO.	CORRECT ANSWER	REFERENCES Narrative Ref. Pages	 P.I. Ref. Frames
1.	c	242-243	1-5
2.	b	243	1-5
3.	b	244	6-11
4.	c	246	6-11
5.	frequency	247	6-11
6.	a	248	6-11
7.	Pierce, parallel	249-250	12-17
8.	C1	251	12-17
9.	Cc	250	12-17
10.	b	252	12-17
11.	tickler coil, series resonant	254	18-21
12.	d	254	18-21

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 1

Delay Lines

QUESTION NO.	CORRECT ANSWER	REFERENCES Narrative Ref. Pages	REFERENCES P.I. Ref. Frames
1	electrical	43	1-7
2.	electromechanical	43	1-7
3.	c. mechanical motion	44	1-7
4.	b. capacitors, inductors	46	8-15
5.	c. 8	47	8-15
6.	the same	48	8-15
7.	d. smaller amplitudes	48	8-15
8.	c. spiral-wound coax, standard coax	49	8-15
9.	b. replace lumped constant and coax delay lines	51	16-20
10.	a. 2000,1000	54	16-20

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 2

Dummy Loads

QUESTION NO.	Correct Answer	REFERENCES Narrative Ref. Pages	 P.I. Ref. Frames
1.	b. Replace the normal load on the equipment under test	81-82	1-6
2.	a. heat	82	1-6
3.	d. resistor	82	1-6
4.	50	83	1-6
[illegible]	900	83-84	1-6
6.	RF antenna	84	7-14
7.	microwave	85	7-14
8.	1000	87	7-14
9.	will	87	7-14
10.	mechanical	87	7-14

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 3

Special Solid State Devices

QUESTION NO.	CORRECT ANSWER	REFERENCES Narrative Ref. Pages	P.I. Ref. Frames
1.	produces, forward	139	1-6
2.	conducts when exposed to light, reverse	141	7-12
3.	d	142	7-12
4.	c	143	13-17
5.	d	144	13-17
6.	b	143	13-17
7.	voltage, light shines on it	144	13-17
8.	a	145	13-17
9.	increase, decrease	148	18-26
10.	c	149	27-29

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 4

FIELD EFFECT TRANSISTORS

QUESTION NO.	CORRECT ANSWER	REFERENCES NARRATIVE REF. PAGES	 P.I. REF. FRAMES
1.	c.	201	1-5
2.	P, N	202	6-14
3.	increase decrease increase	203-204	6-14
4.	large high reduced to zero	204	6-14
5.	MOSFETs JFETs bipolar transistors	208	15-24
6.	b.	208	15-24
7.	d.	208-209	15-24
8.	total electrical isolation source-drain channel	209	15-24
9.	b.	210	15-24
10.	high, voltmeter	213	15-24

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 1

Introduction To Linear Integrated Circuits

		REFERENCES	
QUESTION NO.	CORRECT ANSWER	NARRATIVE PAGE(S)	P.I. FRAME(S)
1.	many	55	1-3
2.	d	55	1-3
3.	b	58	4-11
4.	will	59	4-11
5.	do	59	4-11
6.	must	60	4-11
7.	a	60	12-15
8.	b	61	12-15
9.	counterclockwise	63	12-15
10.	clockwise	63	12-15
11.	c	63	12-15
12.	c	62-63	12-15
13.	in the middle	64	16-18
14.	a	66-67	16-18
15.	smallest, grounded	69	19-20

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON 2

IC Operational Amplifiers

QUESTION NO.	CORRECT ANSWER	Narrative Ref. Pages	P.I. Ref. Frames
1.	a	111	1-3
2.	c	111	1-3
3.	a	111-112	1-3
4.	d	112	1-3
5.	c	113	4-7
6.	b	114	4-7
7.	a	113-114	4-7
8.	d	113-114	4-7
9.	a	117	8-14
10.	would not	118-119	8-14
11.	d	120	15-19
12.	isolated	120	15-19
13.	d	121	15-19